VISUAL SEARCH STRATEGIES AND EXECUTIVE FUNCTIONING IN SOUTH AFRICAN SAILORS

by
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Thesis presented in fulfilment of the requirements for the degree of Master of Sport Science in the Faculty of Education at Stellenbosch University

Article-Format MSc Thesis

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Decmber 2015

DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

The co-author of the three articles that form part of this thesis, Dr Karen E. Welman (supervisor), hereby gives permission for the candidate, Ms Claire N. Walker, to include the three articles as part of a Master's thesis. The contribution (advice and support) of the co-author was kept within reasonable limits, thereby enabling the candidate to submit this thesis for examination purposes. This thesis therefore serves as fulfilment for the degree Master of Science in Sport Science at Stellenbosch University.

28 August 2015

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ABSTRACT

Background: The ability to locate and identify relevant visual information is essential for skilful behaviour as well as to make performance-related decisions. Decision-making is a subcomponent of executive functioning and involves choosing between two or more possible solutions. Visual search behaviour is a dynamic self-organised perceptual skill that is based on the interaction between constraints imposed by the task, the environment, and the individual characteristics of the athlete (Williams, Ward, Smeeton, & Allen, 2004). Technologies-based feedback such as visual search behaviour may provide relevant information to enhance skill acquisition and sport performance in sailors and, as such, its usefulness to sport scientists, coaches and athletes in training is beneficial. Despite recognizing the importance of the visual search behaviour in sailing little research has been done. To the researcher's knowledge, no research has been done on describing South African expert sailors' visual search behaviour and executive functions.

Aim: This investigation set out to determine the i) visual search strategies in two simulated events and ii) executive functions, as an indicator of decision-making skills, of expert South African sailors.

Methods: The investigation followed an observational method descriptive design, where National level South African sailors (n = 61), with an average age of 26 years (SD = 8.88) and professional sailing years of 14 (SD = 7.54), volunteered to participate in the investigation. Visual search strategies of the sailors were determined using a mobile eye tracker during two sailing simulations (computer, n = 24; and radio controlled boats; n = 22). In order to determine the executive functioning (EF) capabilities of the sailors (n = 15), a battery of valid EF tests was compiled comprising the Montreal Cognitive Assessment (MoCA), Wisconsin Card Sorting Test (WCST), Trail Making Test (TMT part A and B), and adapted Stroop Task.

Results: All the sailors fixated considerably more on their own boat than any other fixation location; however the top ranking and successful groups performed fewer fixations (*d* between 0.29 – 0.72) of longer duration (*d* between 0.05 – 0.59) compared to their counterparts in both simulation studies. The helms performed better on the TMT and Stroop task, while the crews achieved better on the WCST (*d* = 0.92 – 1.62).

Conclusion: By describing sailors' visual search strategies, we know what they consider relevant information which contributes to better decision-making and subsequent skilled performance. This may help coaches to enhance sailing performance in less experienced sailors by directing their visual search behaviour to these relevant cues, specifically to look more at their own boat in order to maintain speed and improve performance. The executive functioning skills tell us that successful sailors require the skill to shift their attention and solve problems based on the constantly evolving environment.

Keywords: *sailing; visual search strategies; simulated event; executive functioning*

OPSOMMING

Agtergrond: Die vermoë om relevante visuele inligting op te spoor en te identifiseer is noodsaaklik vir vaardige gedrag sowel as om prestasie-verwante besluite te neem. Besluitneming is 'n komponent van uitvoerende funksionering, en dit behels om die keuse tussen twee of meer moontlike oplossings te maak. Visuele-soekgedrag is 'n dinamiese self-georganiseerde perseptuele vaardigheid wat gebaseer is op die interaksie tussen beperkings wat opgelê word deur die taak, die omgewing, en die individuele eienskappe van die atleet (Williams, Ward, Smeeton, & Allen, 2004). Tegnologieë-gebaseerde terugvoer soos visuele-soekgedrag kan relevante inligting verskaf wat ‘n verbetering teweeg bring in verkryging van vaardighede en sportprestasie in seiljagters en, as sodanig, is hierdie inlingting nuttig en voordelig vir sportwetenskaplikes, afrigters en atlete in opleiding. Ten spyte van die erkenning van die belangrikheid van die visuele-soek-gedrag in seiljagvaart, is min navorsing gedoen. Geen navorsing is al gedoen oor die beskrywing van visuele-soekgedrag en uitvoerende funksies van Suid-Afrikaanse kenner seiljagters, waarvan die navorser bewus is.

Doel: Hierdie ondersoek is ingestel om i) die visuele-soekstrategieë in twee gesimuleerde gebeure te bepaal, en ii) uitvoerende funksies, as 'n aanwyser van besluitnemingvermoëns, van kundige Suid-Afrikaanse seiljagters vas te stel.

Metodes: Die ondersoek het 'n waarnemings-metode beskrywende ontwerp gevolg, waar die nasionale vlak Suid-Afrikaanse seiljagters (n = 61), met 'n gemiddelde ouderdom van 26 jaar (SD = 8.88) en professionele seiljagvaartjare van 14 (SD = 7.54), vrywillig deel geneem het in die ondersoek. Visuele-soekstrategieë van die seiljagters is bepaal met behulp van 'n mobiele eye tracker tydens twee seiljagvaart simulasies (rekenaar, n = 24, en radio beheerde bote; n = 22). Om uitvoerende funksie vermoëns van die seiljagters (n = 15) te bepaal is 'n battery van 'n geldige toetse saamgestel wat bestaan uit die Montreal Kognitiewe Assesering (MoCA), Wisconsin Card Sorting Test (WCST), Trail Making Test (TMT deel A en B), en 'n aangepaste Stroop taak.

Resultate: Al die seiljagters het aansienlik meer op hul eie boot gefikseer as enige ander fiksasie plekke; die top posisie en suksesvolle groepe het egter minder fiksasies (*d* tussen 0.29 – 0.72) van langer duur (*d* tussen 0.05 – 0.59) uitgevoer in vergelyking met hul eweknieë. Die seiljagstuurders het beter presteer op die TMT en Stroop taak, terwyl die bemaning beter tellings op die WCST behaal het.

Gevolgtrekking: Deur die visuele-soekstrategieë van seiljagters te beskryf, weet ons wat hulle as relevante inligting beskou wat bydra tot beter besluitneming en daaropvolgende vaardige prestasie. Dit kan afrigters help om seiljagvaartprestasie in minder ervare seiljagters te verbeter deur hulle aan te wys om hul visuele-soekgedrag op hierdie betrokke leidrade te fokus, spesifiek om meer op hul eie boot te kyk om spoed te handhaaf en te verbeter. Die uitvoerende funksie vermoëns vertel ons dat suksesvolle seiljagters benodig die vermoë om in voortdurend veranderende omgewing hul aandag te kan verskuif en probleme op te los.

Sleutelwoorde: *seiljagvaart; visuele-soekstrategieë; gesimuleerde gebeurtenis; uitvoerende funksionering*

ACKNOWLEDGEMENTS

I would like to express my appreciation and gratitude to the following people who contributed towards making this investigation happen:

Firstly I would like to thank my parents, Mum and Dad, thank you for all your continued love, support and encouragement in everything I have taken on. To my sister, Em, thank you for the random coffee breaks and late night dinners. To my extended family, Andy, Sue, Stew and Duncs, thank you for giving me the option to escape to a comfortable place with a good bed, lots of laughs and great food.

Secondly, a huge thank you to Michelle, you have been my rock throughout this year, you were there through all the highs and lows, you kept me motivated and made me smile when I needed it most.

Dr Karen Welman (supervisor), thank you so much for your continuous guidance, advice and support. For the countless hours spent in your “docsbox” and the many personal sacrifices you have made for me over the last two years, I am truly grateful. Thank you for taking on my crazy ideas, and supporting my passion in sailing.

Acknowledgement and appreciation is extended to Prof Elmarie Terblanche, Department of Sport Science, Stellenbosch University. Thank you for giving me the opportunity to complete my Master’s degree, this investigation would not have been possible without your support.

Thank you to all the willing sailors for their participation, enthusiasm and help in making this investigation an enjoyable experience.

To Grant van Velden and the Centre for Human Performance Sciences (CHPS), for the use of the ASL Mobile Eye Tracking System.

To all my friends and colleagues, thank you for your friendship, advice and all the adventures. I truly could not have achieved this without every one of the above mentioned people, so thank you!

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KEY TERMINOLOGY

Abilities – when an individual is born with natural competence in an activity.

Burgee – a device used to determine the direction of the wind, usually placed at the top of the mast.

Cognitive flexibility – involves the ability of an individual to change how they think about something. For example being able to switch between tasks of varying priorities or take advantage of an opportunity (Diamond, 2013).

Committee boat – an anchored boat indicating the right-hand limit of the start line; races are started from the committee boat by means of flag and sound signals.

Executive function – an umbrella term for the control or management of cognitive processes such as working memory, cognitive flexibility and inhibitory control.

Expert – demonstration of superior performance in sailing at a competitive level, either nationally and/or internationally.

Failure to maintain set – response consistency, when the participant is able to make between five and nine correct responses at a time; reflects efficiency during the test (Tchanturia et al., 2012).

Fixation – when an individual holds their gaze on a specific point in order to gain information.

Fixation duration – a fixation lasts a minimum of 100 ms while the foveal vision remains still or within 3° of the visual angle (Wilson, Vine, & Wood, 2009).

Fixation location – the specific gaze point the individual is fixating on.

Fixation frequency – the number of fixations per second.

Inhibitory control – is the ability of an individual to change the way they react to certain situations by overriding a habit or predisposition (Diamond, 2013).

National sailor – a sailor who has competed in a minimum of one national sailing event between January 2012 and January 2015.

Optic array – contains all the visual information available at the retina, specifically how light is structured at a particular vantage point.

Percentage viewing time – the cumulative amount of time the participant fixated on a fixation location, in percentage (%).

Perseverative errors – only preservative responses that are not errors.

Perseverative responses – any response that fitted the criteria for perseveration.

Pre-cue – an advanced cue which if interpreted properly aids the athlete in making an appropriate decision.

Reaction time – the time taken from the identification of the stimulus or input to the initiation of the movement or action.

Sailing class – boats can be categorized into many classes, the three mentioned in this investigation include:

- dinghies, which are generally small, light boats.
- keelboats, which are generally larger, heavier boats with a fixed keel, usually sailed in the ocean.
- multihulls, which includes boats with a hull in two parts.

Search rate – includes the total number of fixations, the average fixation duration, and the fixation frequency.

Skills – when an individual acquires or learns how to do something well.

Start – the imaginary line created by the committee boat and a pin mark, the sailors are required to wait behind this line until a flag is dropped indicating the start of the race.

Tack – when the boat turns into the wind causing the sail to flap and change to the opposite side of the boat (Glossary of sailing terms, 2007).

Tau – an optic variable which gives an individual information regarding time remaining before contact between the athlete and object.

Tell tail – an indicator attached to the sail, giving information pertaining to the wind flow across the sail.

Windward – refers to the side of the boat the wind hits first or sailing towards the direction the wind is coming from (Pluijms, Cañal-Bruland, Kats, & Savelsbergh, 2013; Glossary of sailing terms, 2007).

Windward mark – the floating buoy situated at the top of the course, this indicates the end of the first leg and the beginning of the second (Pluijms et al., 2013).

Working memory – when an individual holds information relating to the task in mind for a brief moment of time and is able to mentally work with it in order to plan and update (Diamond, 2013; Gazzaley & Nobre, 2012; Baddeley, 1986).

LIST OF ABBREVIATIONS

APA	American Psychological Association
BRG	Bottom ranking group
CF	Cognitive flexibility
EAT	Ecological approach theory
EF	Executive functions/functioning
FTMS	Failure to maintain set
IC	Inhibitory control
IPM	Information processing model
LTM	Long-term memory
MB	Movement behaviour
PE	Perseverative error
PR	Perseverative response
RCL	Radio controlled laser
RT	Reaction time
STM	Short-term memory
TMT	Trail making test
TRG	Top ranking group
VMW	Visuomotor workspace
WCST	Wisconsin card sorting test
WM	Working memory

PREFACE

This thesis follows an article-format based on three separate, but equally important, parts of the investigation. The first chapter is a general introduction and overview of the research topic, followed by a more detailed general literature review (Chapter 2) on the key concepts of the research question, including the problem statement, main research aim with objectives and the rationale for the investigation. Hereafter research article one (Chapter 3) and article two (Chapter 4) will address the first two objectives of the investigation. While the third research article (Chapter 5) addresses the remaining two objectives of the investigation. Chapter 3 was submitted for review to the *International Journal of Sports Science and Coaching* and follows the Vancouver referencing format, Chapter 4 was prepared for the *Journal of Sports Sciences*, following the American Psychological Association (APA) referencing format and Chapter 5 was submitted to the *Journal of Sports Science & Medicine* following the Harvard System referencing format, in accordance to the respective journal guidelines. Finally the thesis is concluded with an overall discussion with conclusion and recommendations (Chapter 6). Chapters 1, 2 and 6 follow the APA referencing format.

CHAPTER 1
INTRODUCTION

Recently sailing has been receiving more and more attention from both a competitive and research perspective. The international sailing community has seen a huge change in the professionalization of the sport, with more sponsorship opportunities and high performance aspects to the sport. This may be due to the fact that the design of the boats have changed dramatically, making them faster and more thrilling. As a result the sailors have to be physically and mentally conditioned in order to control the boats. Furthermore, with the development of video technology more spectators from around the world are able to watch and support the sport. In terms of research, sailing in relation to many other sports has received minimal interest. However, this is also changing as sailors attempt to keep pushing the boundaries in all aspects of the sport.

Sailors can choose to compete in a variety of classes, ranging from Radio Controlled Boats to Ocean-going Yachts, as well as racing formats, from fleet to team racing. However, the strategies and tactical manoeuvres involved in the different classes and formats are fundamentally the same. As a result in order to be successful in the sport sailors cannot merely be physically fit, they also need the necessary technical and decision-making skills. For example, if there is light wind over the course sailors may identify an area of stronger wind and decide to sail towards that area in order to increase their boat speed. In short course racing the sailors are unrestricted in the track they choose to navigate the course, however they are required to round certain marks in a predetermined order. Thus the decisions they make will determine how quickly they can get their boat around the marks.

Various researchers have found that expert sporting performance is influenced by perceptual-cognitive skills, and in particular an athletes skill to anticipate an accurate response in a given situation (Williams, Hodges, North, & Barton, 2006; Paterson, 2010; Spittle, Kremer, & McNeil, 2010). In order for athletes to anticipate a response they rely on their visual skills to extract the most relevant information from their environment (Abernethy, Zawi, & Jackson, 2008; Savelsbergh, Williams, van der Kamp, & Ward, 2002; Williams, Ward, Knowles, & Smeeton, 2002). For example, expert sailors are more able to extract significant information from other boats, wind direction, current flow and waves when compared to near-expert or novice sailors (Araújo, Davids, Diniz, Rocha, Santos, Dias, & Fernandes, 2014). They are then able to use this information to anticipate any wind shifts and as a result construct a superior strategy to navigate the course; or they could deduce that their opponents may perform specific actions and subsequently react with the best possible tactical manoeuvre such as to either tack or duck behind them.

Previous research comparing expert and novice athletes have indicated that expert athletes in a sport use more efficient visual search behaviours in order to gain the information and make adequate decisions within the specific context (Afonso, Garganta, Mcrobert, Williams, & Mesquita, 2012; Huys & Beek, 2002). The variables investigated in visual search research give an indication of how athletes pick-up information, i.e. where they detect the cues, and how much they rely on these in order to make decisions to achieve their goal (Williams et al., 2002). In other words visual search research provides information pertaining to the athletes' cognitive-processes and decision-making skills (Roca, Ford, McRobert, & Williams, 2011; McPherson & Kernodle, 2007).

Success in a sailing race is dependent on the interaction between the sailor, the boat and the surrounding environment. Therefore, the importance of identifying critical cues in the environment highlights the need for coaching appropriate information identification processes and subsequent decision-making skills in order to improve performance. A study by Araújo, Davids & Serpa (2005) found that the decision-making skills of expert sailors far outweigh their near-expert and novice counterparts. This knowledge of the decision-making processes used by the expert sailors could yield more information about how they access and use the available information prior to making a decision. For instance, some researchers have shown that sailors who spend more time looking inside their boat during a specific action are more successful compared to others who look outside the boat more often (Pluijms, Cañal-Bruland, Hoozemans, & Savelsberg, 2014).

Research on the executive functioning capabilities of individuals has identified a positive link between the physical and mental challenges associated with exercise and sport participation (Alves et al., 2013; Etnier, Nowell, Landers, & Sibley, 2006; Colcombe & Kramer, 2003). Appropriate decision-making involves an understanding of the choices between possibilities and performing the appropriate actions for a specific context (Clarke, Brummer, Kluka, & Goslin, 2009). Executive functions (EF) are collective cognitive functions that guide planning, problem solving, organising and directing the body to perform functional activities. In addition EF incorporates an individual's ability to develop initiatives, contemplating consequences, making appropriate decisions, their working memory (WM), prioritising, paying attention, focusing on critical cues, pursuing a goal, shifting between tasks, and ceasing a completed action (Barkley, 2012). To the researcher's knowledge no research has been done highlighting the executive functioning skills of sailors.

With the recent revolution of the equipment required to gain information pertaining to a sailor's perceptual skills, a few studies have examined the visual search of sailors. However, these studies have selected a specific area of the race or technical skill within the sport (Manzanares, Menayo, Segado, Salmeron, & Cano, 2015; Pluijms et al., 2014; Pluijms et al., 2013). Only one research study could be found which looked at the race as a whole (Araújo et al., 2005). Given the essential role perceptual-cognitive skills play in expert performance, this relative limited research identifying these skills during a specific manoeuvre of a sailing race or the race as a whole appears to justify further research in this area.

CHAPTER 2
GENERAL LITERATURE REVIEW

2.1 Introduction

Although sailing is a popular sport in Europe, Australia and USA as well as an Olympic event, very little research has focused on examining the perceptual skills required to perform optimally during a race. The reason for the limited research on this topic may be due to previous equipment limitations and other practical reasons, specifically concerning eye tracking devices, waterproof video cameras and determining decision-making skills while on the water. On the other hand, in South Africa it may also be because sailing is not considered a mainstream sport and thus is not often chosen as a research area. Some studies have described the physiological and physical demands of dinghy sailing (Vogiatzis et al., 2011; Neville & Folland*,* 2009; Castagna & Briswalter, 2007; Cunningham & Hale, 2007; Spurway, 2007; Tan et al., 2006; Vangelakoudi *et al.,* 2006; Mackie, Walls, & Gale, 2002; Legg, Mackie, & Smith, 1999a); however very limited associations can be drawn from these results with regards to the sailors' perceptual skills such as their visual search strategies and executive functions.

2.2 The Nature of Sailing

Sailing is a unique sport, it is dynamic in nature and as a result there are many variables which cannot be controlled by the sailor. However to be successful a sailor must adapt his/her movements and decisions to these variables. These variables include the wind (which often differs in strength and direction), tide (either incoming or outgoing), waves (for example short, choppy waves or big swells), the specific location of the marks (determined by the race committee), the number of races a day (determined by the race committee) and the location and actions of competitors on the race course. For instance, the fastest track around the course varies as the conditions change, the wind and waves change continuously during the race which in turn affects the speed and angle of the boats. This further adds to the unpredictable environment factors in the sailing (Pluijms et al., 2013).

Sailing races can take place in a number of ways, for example one can either race in cross Atlantic races (across the ocean), fleet races (around a long course against a group of boats) or match races. Match racing has been described as a duel between two boats in which the goal is to successfully combat the environmental conditions in order to beat the opponent to the finish line (Araújo et al., 2014). Typically a National or International race for the majority of sailing classes consists of a start, upwind and downwind legs, mark roundings and a finish. During these stages sailors continuously make decisions based on their perception of the situation. Sailors make their decisions predominantly prospectively. This means that they base their decisions not only on the intermediate context, but on information obtained from a wider perspective, which allows them a greater chance of predicting or anticipating what may happen at a later stage (Araújo et al., 2005). Athletes in most other sports on the other hand may predominantly focus on the intermediate context, i.e. what you can do here and now. As shown by Pluijms et al. (2013) the dynamic nature of sailing creates many opportunities for decisions and subsequent actions.

Although a simulation may not directly replicate a natural environment, the sailor is still required to manipulate the boat and interact with the constantly changing task and environmental constraints (Araújo, Diniz, Passos, & Davids, 2013). As stated by Araújo et al. (2014) these constraints include the wind direction and movements of the opposition. In the current research, both of these constraints were investigated.

Manzanares et al. (2015) stated that sailing requires a high level of visual perception and that it is crucial to extract relevant information from the environment for successful performance. The athlete is required to anticipate what may happen in an unpredictable environment, adapt to situations which may be pre-planned and/or spontaneous and then make a decision. This supports to important role visual behaviour plays in decision-making skills of sailors which would then influence skill-based performance. However, one must not forget that sailors also rely on perceptual information picked up through other senses such as tactile, auditory and the vestibular systems.

2.3 Motor Behaviour Theories for Movement Preparation

Motor behaviour theories help us to understand how an individual acquires motor skills as well as the factors which influence motor skill performance. This again allows sport scientists to identify possible movement challenges and to develop intervention strategies to overcome these challenges.

Two main motor behaviour theories will be highlighted in the following sections i.e. the Information Processing Model (IPM) and the Ecological Approach Theory (EAT). The IPM describes how an individual gains information and uses it to successfully perform a skill; and accordingly perception is a process of assigning meaning to cues via an inferential process (van der Kamp, Rivas, van Doorn, & Savelsbergh, 2008). According to this theory, information must first be encoded before perception and action become meaningful and the individual relies on their memory for this processing. For this reason it is believed that better skilled athletes have an enhanced ability to process visual pre-cues compared to lesser skilled athletes or non-athletes.

On the other hand, EAT explains how coordinated movements are directly controlled through the dynamic interaction of the individual and the environment (Gibson, 1979). In addition, the EAT highlights the perceptual-action cycle as the suggested mechanism behind an individual's movement coordination and their perceptual visual skills. More specifically this mechanism is responsible for directly coupling the information the individual receives through their vision (perception) and the limb movement (action) required to perform the desired skill (van der Kamp et al., 2008; Michaels, Zeinstra, & Oudejans, 2001; Michaels & Beek, 1995). Hence, unlike the IPM, the EAT states that skilled athletes have the ability to directly detect relevant cues which will allow them to predict the future event without the need for intermediate processing stages.

Both theories however attempt to explain how the extraction of information from the environment, via visual search strategies, could enhance visual anticipation in expert sailors. As a result of the nature of the study design and methodology both theories are considered. The somewhat controlled environment of the simulations as well as the assessment of executive functioning may be better supported with the IPM; however the simulation still allows some functional coupling between perception and action, which may be better explained through the EAT.

2.3.1 Information Processing Model (IPM)

In all aspects of life individuals have to deal with a constant flow of sensory information through which they sift in order to identify the most important and relevant aspects to interpret and make sense of. Researchers have suggested that the way individuals deal with this information can be compared to a computer, in that we follow similar processes in order to make sense of everything. Both individuals and computers have an input system, either through typing on a keyboard or a visual stimulus, an ability to process this information and a means of displaying the information, either on the screen or through an action or movement. Simply put IPM's give an example of how we are able to identify a stimulus, select a response and carry out a movement. The IPM offered by Welford (1968) is based on this concept; see Figure 2.1 for a graphical representation. He states that an individual takes in information (input) from their surrounding environment through both external and internal sources; these sources include an individual's visual, auditory and proprioceptive senses. This information gained is then temporarily stored in the short-term memory (STM), where it is transformed into something more meaningful for the individual and sorted for relevancy. Welford refers to this transformation step as the perceptual mechanism. The perceptual mechanism allows the individual to make sense of the information and use it to help make an appropriate decision, while the sorting process determines which cues are significant and which are not. Relevant cues are aspects in the environment on which an athlete needs to focus in order to pick up necessary information to make the most appropriate decision (Saariluoma, 1985). An example of relevant cues in sailing were identified by Manzanares et al. (2015), these included the start marks, wind direction, bow of the boat, watch, boom, mast and tell-tails on the sail. These cues were similar to those identified by Pluijms et al. (2013). This interpretation of information is critical due to the fact that if an individual does not know what an input looks like, it will have no meaning. For example, if sailors do not know what wind looks like when it touches the water they will not know how to make sense of the darker and lighter areas on the course. The significant information is then compared to information which is retrieved from the long-term memory (LTM). The information in the LTM is a result of past experiences, knowledge and practice. This comparison between the two sets of information helps the individual arrive at a decision, once the decision is made the effector mechanism takes over. Welford (1968) describes the effector mechanism as the motor programme which will be put into action, in order for this to happen the muscles receive impulse via the nervous system. The action or response and following result are then stored in the LTM for a future event, which in turn assists in the learning process of the individual. Welford's IPM assumes that the behaviour of an individual is a result of these stages and that each stage operates independently in order for the individual to successful respond to a stimulus.

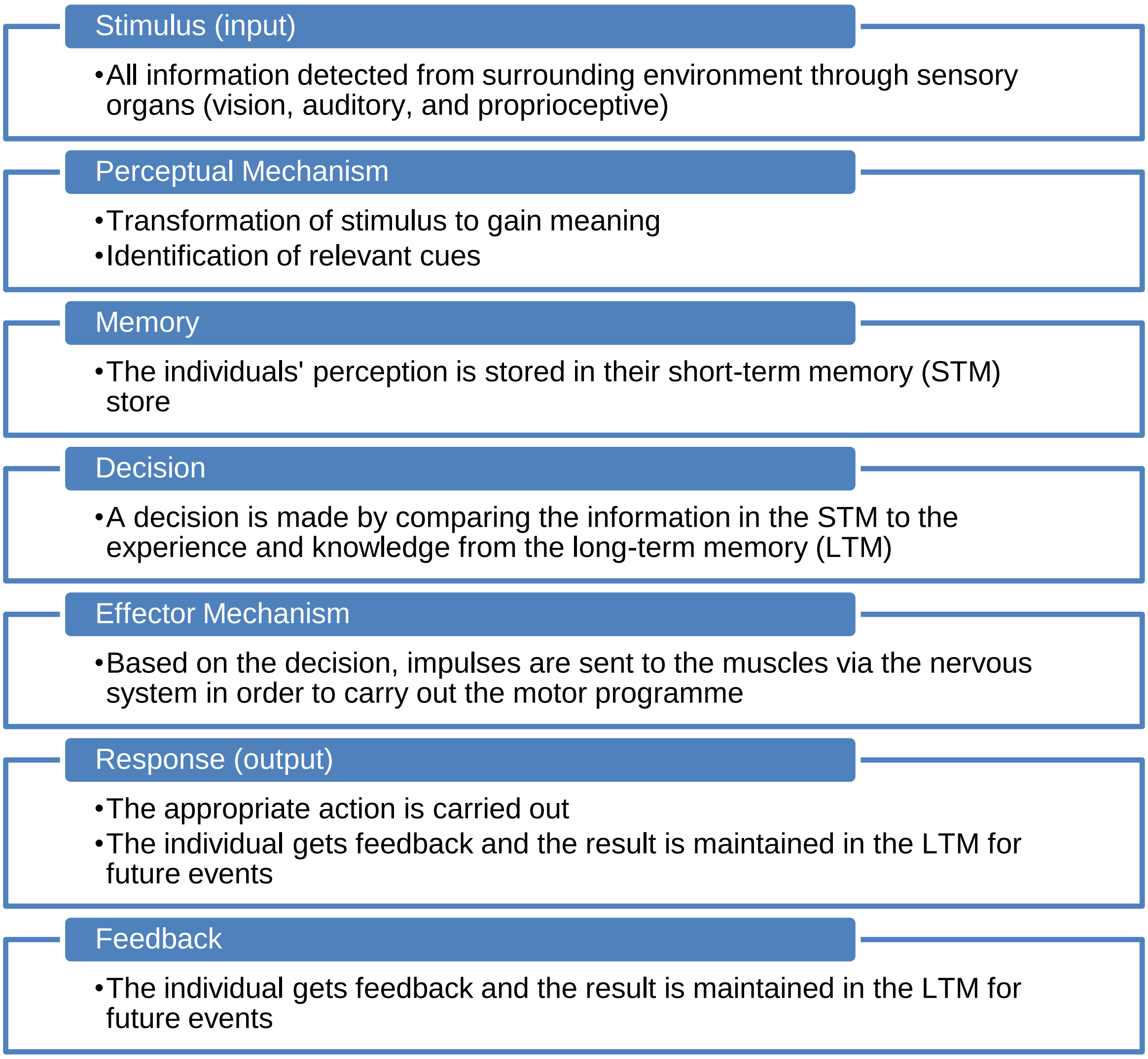

Figure 2.1 Illustration of the Information Processing Model (adapted from Welford, 1968)

In short, the IPM is based on how an individual deals with the enormous amount of available information in order to perform the necessary response. The IPM suggests that the athletes continuously process the information from their environment, which allows them to change their actions or behaviour as the environment changes. In sailing for example, the sailor is continuously monitoring the wind direction and speed in order to take advantage of a change. An important aspect of all IPM's is that the individual relies on their memory in order to make sense of their environment and act within it. The IPM suggests that the athletes depend on their previous experiences and knowledge in order to determine the correct motor programme to successfully respond to the situation.

Various researchers have found that expert athletes have notably better perceptual-cognitive skills than near-expert and novice athletes (Pluijms et al., 2013; Williams, Ford, Eccles, & Ward, 2011; Mann, Williams, Ward, & Janelle, 2007; Williams & Ericsson, 2005; Abernethy, Gill, Parks, & Packer, 2001). This suggests that expert athletes are more able to pick-up the most appropriate perceptual information (relevant cues), at the appropriate moments which enhances their anticipation (Pluijms et al., 2013; Savelsbergh, Haans, Kooijman, & van Kampen, 2010; Mann et al., 2007). They use the relevant cues then to assist and guide the applicable motor responses to achieve success in their sport context (Pluijms et al., 2013). Researchers have also suggested that expert athletes are able to consistently make better decisions and have an ability to predict the outcome of a situation (Mann et al., 2007; Williams, Davids, & Williams, 1999).

2.3.2 Information Processing and Anticipation

Researchers suggest that the ability to anticipate or predict when something and/or what may happen in your sporting environment, such as what your opponent will do next, is critical for successful performance (Piras, Lobietti, & Squatrito, 2014a; Williams et al., 2011; van der Kamp et al., 2008; Williams, 2000; Abernethy, Wood, & Parks, 1999). Anticipation includes visual skills as well as perceptual and cognitive skills and is especially critical for decision-making (Piras et al., 2014a; Germain & Tenenbaum, 2011; Borysiuk & Waskiewicz, 2008). A requirement for anticipation in a task or activity is for the athlete to use early information to speculate an approaching event in order to respond quicker (Germain & Tenenbaum, 2011; Abernethy et al., 2008). In order to save time when responding or reacting to a stimulus athletes may refer to their past experiences and/or advanced identification of the critical information. For example sailors who have competed at the same venue with similar conditions may remember that a successful strategy was to start at the committee boat end of the line and be the first boat on the right hand side of the course, thus they can anticipate a wind shift on that side of the course.

Expert athletes are better able to recognize patterns within their environment, have superior anticipation and are more capable when adapting to a change within their environment (Ward & Williams, 2007; Williams & Davids, 1995; Abernethy, 1990a). Most comparison studies suggests that expert athletes, compared to a near-expert and novice athletes, have more flexible and detailed representations of the situation found in the performance context (based on the perceptual experience hypothesis) and thus have enhanced anticipation skills (Huys, Cañal-Bruland Hagemann, Beek, Smeeton & Williams, 2009; Williams, Huys, Cañal-Bruland & Hagemann, 2009; Abernethy & Zawi, 2008; Mann et al., 2007; Ward & Williams, 2007; Jackson, Warren & Abernethy, 2006). In other words, expert athletes have more experiences to access and compare to in their LTM, which allow them to adapt to the situation very quickly (Williams & Davids, 1998; Abernethy, 1991). More specifically expert athletes have enhanced declarative and procedural knowledge, which helps them to make effective decisions and tactical strategies. Furthermore, Williams et al. (2002) suggest that expert athletes are better able to predict what their opponent may do as a result of an improved ability to attend to the relevant cues. It has been suggested that anticipation may go wrong if the athlete identifies the correct cue, but fails to use the information to make a successful decision; or if the athlete identifies a distractor cue (Williams et al., 2011). For example if sailors identify an approaching opponent who they are required to avoid and they do so unsuccessfully they have made an incorrect decision.

Perceptual anticipation is when an athlete is able to anticipate what will happen before it actually does and consequently plays a critical role in decision-making as well as reducing reaction time (RT) (McMorris, 2004). Evidence from research in racket sports suggests a strong relationship between expertise and the process of gaining information from the critical kinematic cues of the stimulus (Abernethy et al., 2001). Depending on the performance context perceptual anticipation comprise of two types of anticipation, specifically spatial and temporal anticipation. Spatial anticipation refers to the skill of an athlete to predict what may happen in the future, while temporal anticipation refers to predicting when an event or action performed by an opponent may take place (Schmidt & Wrisberg, 2008; Borysiuk & Sadowski, 2007). An example can be taken from sailing in that sailors may predict when the wind will shift as a result of timing the wind shifts and subsequently decide on an appropriate movement beforehand or being able to predict that their opponent will tack beneath them when approaching the windward mark. In terms of the information processing the model suggests that different tasks, be it in the same or different sports, take place under different situations with varying time limits (Schmidt & Wrisberg, 2008). In sailing for example the sailors may come across a situation where they have a few seconds to respond or where they are able to plan their decision, such as their strategy for the race.

Visual anticipation is a perceptual-cognitive skill that purposely refers to the skill of making precise predictions from limited visual pre-cues (van der Kamp et al., 2008; Poulton, 1957). Visual anticipation becomes effective when the athlete can fixate on the correct object or location and can identify the subtle difference between actions. Research aimed at identifying the visual anticipation of athletes has predominantly used temporal or spatial occlusion paradigms, which involves allowing the athletes to only view a part of a movement from their opponent, such as the initial 150ms of the serve, and then they are required to predict where the ball will land (Jackson & Mogan, 2007; Williams et al., 1999; Starkes, Edwards, Dissanayake & Dunn, 1995). For example a cricket batsman may notice that the bowler is releasing the ball slightly higher and know that the ball will be a full toss (Ward & Williams, 2007).

Experts and novices can develop anticipation through learning to identify relevant visual cues (Abernethy et al., 2008; Savelsbergh et al., 2002; Williams et al., 2002). Given that more successful athletes are able to identify relevant cues in their environment via anticipation and attend to these more than they would to less important cues, this will result in improved RT (Borysiuk & Sadowski, 2007; Abernethy et al., 1999; Alain & Proteau, 1980). The key characteristics for anticipation include selective attention, WM (STM) and pattern recognition (Gazzaley & Nobre, 2012; North, Williams, Hodges, Ward, & Ericsson, 2009; Alexandre, 2005; McMorris, 2004; Williams & Davids, 1998). Working memory is when an individual maintains information relating to the task in their mind for a brief moment of time (Gazzaley & Nobre, 2012). Based on this definition an individual's WM can be associated with their executive functioning skills.

2.3.3 Information Processing and Reaction Time

There is no doubt that many sports require the athletes to carry out skills very quickly if they want to be successful (Soto-Rey, Pérez-Tejero, & Rojo-Gonzáles, 2014; McMorris, 2004). Take for example, a goal keeper in hockey or soccer player defending a shot, a sprinter reacting to the starting gun or a sailor reacting to the environmental conditions or the actions of another boat. Reaction time has been described as the time it takes for an individual to identify a stimulus or input and initiate a response, i.e. does not include the movement (Collet, 1999). This is often confused with response time, which is the time taken by the athlete to identify a stimulus, as well as initiate and complete the movement (output).

Reaction time can be divided into simple and choice RT. Simple RT refers to when there is only one stimulus and the same response or action is required from the athlete (Collet, 1999). For example in sailing, a sound signal can be heard and a flag is dropped to indicate the race has started, at this signal all racing boats will cross the start line. Whereas choice RT refers to when there are a number of stimuli and an athlete has to identify the different response for each. Hyman (1953) and Hick (1952) published experiments on RT, they concluded that as you increase the number of stimulus individuals should react to the RT increases (Maleki, Mousavi, Aghazaeh, Parikhani, Ardabili, & Isazadeh, 2014; Schmidt & Lee, 2005).

The information processing theory places great importance and reliance on the role of memory in the process as well as response, reaction and movement time. However this model of information processing has been criticised by others as being such a time costly process (Raab, de Oliveria, & Heinen, 2009; McMorris, 2004). In other words, the time it takes to generate all possible options and then choose the most appropriate one (Raab et al., 2009). In sport, athletes often have split seconds to make a decision and perform the relevant action. For example in sailing, as a result of the speeds the boats can travel during strong wind, the sailors have very little time to react if something happens in front of them, such as a capsize or opposition making an unpredictable move. Another criticism is at the stage where the relevant information in STM is compared to that in the LTM. It suggests that a decision and action can only be completed if the individual has prior experience of the event, thus further cognitive processes would be needed (Raab et al., 2009; McMorris, 2004). Consequently other more contemporary theories have been suggested such as Ecological Approach Theory.

2.3.4 Ecological Approach Theory

The EAT suggests that the decisions athletes make and the subsequent actions they perform are a result of the dynamic interaction between the individual and the surrounding environment. Thus, the concept behind the theory is largely concerned with how the individual interacts with the environment based on the task at hand (Craig & Watson, 2011; Dicks, Davids & Button, 2009). Gibson (1979) suggests that the movements of an individual generate information, which in turn supports further movement. This is further examined by Renshaw, Davids, and Savelsbergh (2010), who suggest that individuals search for relevant informational cues within their environment in order to succeed in their task. The information they gain results in the generation of a behaviour or action which leads to the detection of more information. Kirlik (2006) summarises this by suggesting that individual acts to create information, which consequently guides further action. Gibson (1979) refers to this relationship as a perception-action cycle. He suggests that there lies a direct relationship between an individual’s perception of the situation and their subsequent movement.

Button (2002) suggests that the informational sources provided by the environment are always available for the individual to find, regardless of the venue. The researcher recommends that it is necessary for athletes to move through the environment in order to identify the important characteristics and allow them to become more obvious. Araújo et al. (2010) argue that a sailor has the opportunity to explore the race course prior to the start of the race in order to gain information related to performance. By doing so, the sailor has the opportunity to evaluate the environment and form a strategy based on the wind and wave conditions or tidal effects (Araújo et al., 2010). This ability of an individual to detect the relevant cues may help to predict the future or anticipate an event. The EAT refers to these characteristics as affordances for action (Gibson, 1979). Affordance can further be explained as an invitation to act within the immediate environment or as an opportunity for action (Craig & Watson, 2011; Dicks et al., 2009). According to the theory no two opportunities are ever the same, thus the “affordances may be similar but never identical” (McMorris, 2004). These affordances are always present in the environment; however it is up to the individual to actively search for the important affordances to determine which actions can be carried out and which cannot (Craig & Watson, 2011; Button 2002). In sailing for example, if the sailors notice that the wind has shifted to the right by fifteen degrees (affordance) 30 seconds prior to the start of the race, they should aim to start as close to the committee boat end of the line to improve their chance of winning. During the race the sailors are constantly monitoring the conditions around them and always looking for an affordance which may improve their performance. However, as Araújo et al. (2010) suggest, the action the sailors finally decides to do is also based on their physical characteristics and skill capabilities. Gibson further suggests that the perception of an opportunity (information) and the action (movement) are linked within a particular performance context (Fajen, Riley & Turvey, 2009), and this is referred to as ‘perception-action coupling’ (Gibson, 1979).

Renshaw et al. (2010) state that with these components of the EAT in mind an individual arrives at a decision as a result of an emerging process which has been developed as the individual explores the situational constraints. As individuals spend more time doing a task or moving in an environment, they become more attuned to the available characteristics and are able to pick-up more specific, relevant and precise information. Some researchers have suggested that a sailor’s decision-making process may be viewed as an evolving co-adaptive behaviour (Araújo, Davids, & Hristovski, 2006; Araújo et al., 2014). The EAT states that when individuals, such as sailors, make a decision they do so by taking into account what is on their mind as well as the constraints of their immediate environment (Araújo et al., 2014; Richardson, Shockley, Riley, Fajen, & Turvey, 2008). Araújo et al. (2014) state that the separate decisions made by sailors should not be considered on their own but rather coupled with each other. The reason being, that a decision made may be as a result of a previous decision or action, which in turn could affect a future decision or action. One must also remember that the decision an individual makes is also determined by the overall performance goal (Araújo et al., 2014; Araújo et al., 2005). For example in a sailing match race an incident involving the opponent on the start line may change their strategy on the upwind leg.

When performing an action, the EAT suggest that the initial message is relayed from the CNS. However, it differs to the IPM in that the message is very broad, such as ‘tack’. It is then up to the perception-action coupling to decide specifically how to perform the desired movement, i.e. tack in different environmental conditions, for example when the wind is stronger the tack will happen faster. Consequently, decision-making depends on the performance context and how the individual wants to achieve the desired outcome. The action the individual performs is determined by the environmental and individual constraints, such as the wind or social context and the individual’s strength and fitness level. Each individual may perform the same skill differently as each has different strengths and weaknesses.

From a coaching or training point of view it is very important that the athletes train by keeping the information sources and the desired action together. Thus, helping the individual learn where to search for the relevant cues required for performance of a successful action. This is often neglected during training.

There are two major criticisms to the ecological psychology approach. The first is that the researchers refuse to accept that memory plays any role in the process of performance or behaviour, and it is suggested that this contradicts “common sense” (McMorris, 2004). As individuals perform certain tasks more often (practice), their ability to fulfil the necessary objectives in these tasks improves. Thus, without some sort of memory of practice the individual would perform the task the same each time and no improvement will be observed. Regardless of the individuals experience and level of play, there are always times when the individual performs an action which may not be optimal. To the EAT the perception of information is direct and does not require past experience in order for the individual to have a perception. The environment contains all the information required for the necessary action; however it is important to note that the individual needs to actively seek out the information (Bardy & Warren, 1997).

2.4 Perceptual-cognitive Skills

Perceptual-cognitive skills are the ability to acquire relevant information about the performance context which allows the athlete to select and execute the most appropriate movement/action (Patterson, 2010; Mann et al., 2007). Previous research focusing on the perceptual skills of athletes has identified differences between expert and non-expert individuals within any given task, for example chess or defending a soccer shot (Charness, Reingold, Pomplun & Stampe, 2001; Savelsbergh et al., 2002). Therefore perceptual-cognitive skills, such as visual anticipation, could contribute to accurate perception, action and precise decision-making in sailing.

2.4.1 Visual Search Strategies

The visual system and associated eye movements include hardware and software skills (Abernethy, 1996; Williams, Davids, & Burwitz, 1994a). The hardware skills describe the structural non-task specific abilities behind the visual system such as visual acuity, binocular abilities, depth perception, ocular health, colour discrimination and peripheral vision that does not involve cognitive skills. While functional software skills describe how the individuals use the visual system to gain information by which they visually guide their actions, such as visualization, visual concentration, visual perception, visual RT and visual search strategies (Ludeke & Ferreira, 2003; Ferreira, 2001). This thesis only focuses on the perceptual-cognitive skills i.e. visual search strategies of expert South African sailors.

Visual search strategies are used to quickly and consciously gain information from the visual environment, which is deemed relevant to the specific task (Piras, Pierantozzi, & Squatrito, 2014b). This means that during visual search, the athlete identify important targets or cues within a predetermined area in their visual field (Schuster, Rivera, Sellers, Fiore, & Jentsch, 2013). Often the difference between a relevant cue (target or location) and a distractor (irrelevant cue) come down to only a few small features or characteristics, such as the angle of the burgee or the height of the wave in front of the boat. Investigations on perceptual visual skills often include the target locations or areas of interest, search rate as well as the number of fixations and the duration; whereas some have explored the quiet eye (Vickers, 2009; Vickers, 2006).

Visual search behaviour involves shifts between ‘fixations’ and ‘saccades’. Fixations are determined when individuals hold their gaze on a specific point, with the visual field remaining stable, in order for the individual to identify the critical information from the environment necessary for the action (Vickers, 2009). A fixation typically last for a minimum of 100 ms in which the foveal vision remains still or within 3° of the visual angle (Wilson et al., 2009; Carpenter, 1988; Carl & Gellman, 1987; Optican, 1985). During a fixation the individual is able to consciously process information. Saccades on the other hand are defined as rapid, ballistic eye movements which typically last less than 100 ms (Vickers, 2009; Vickers, 2006). During a saccade the point of gaze moves from one object or location to another and the individual is unaware of what may have been seen between the two locations (Johns, Crowley, Chapman, Tucker, & Hocking, 2009; Findlay & Walker, 1999).

Ripoll (1988) identified four aspects which make up visual search strategies: (i) the fixation location, (ii) the fixation duration at each location, (iii) the number of fixations, and (iv) the sequence of fixations. Williams et al. (1999) suggest that the fixation location determines the area where the athlete may find the most relevant information to execute the appropriate action and thus give an indication on the decision-making procedure, and that the number of fixations and total time spent in each location gives an indication of the importance of the information extracted from the location. Consequently, suggesting that the athlete is gaining information through his/her visual system being focused on specific relevant information used as anticipatory cues, while also able to pay attention to surrounding areas.

Visual search strategies may vary between different motor tasks i.e. targeting, interceptive and tactical tasks. Sailing includes tactical locomotion tasks, considering that the environment is dynamic and the athlete is required to read the complex environmental patterns and mostly have to manoeuvre around targets (marks) in order to achieve success, which is referred to as visual spatial intelligence (Vickers, 2007). For instance, the performance context in which the manoeuver takes place in is very important in sailing, if the environment changes such as the wind pressure increases or decreases the sailor’s manoeuvres will alter to be more effective in that situation.

According to Pomplun et al. (2013) the primary mechanisms that enables athletes to successfully perform visual search strategies is visual attention. Attention can be explained as how we select the information from the environment for further processing. The visual search and attention relationship is unique in that when our gaze shifts from one location or object to another, a shift in attention precedes the saccades in the visual search pattern. In other words attention moves faster than the eyes. Vickers (2009) is an advocate of the theory that when the athletes shift their gaze, they also shift their attention to that specific point, however while an athlete’s gaze may remain on a specific location, the duration of the fixation point may not always be an indicator of attention (Vickers, 2009). Vickers (2009) suggests that the more control individuals have over their visual search strategies, the better their accuracy and precision in the task, which may result in enhanced performance.

The Nodine-Kundel visual search and detection model was developed in 1987. It suggests that individual differences between athletes and the context within the visual field affect performance and decision-making in the situation (Schuster et al., 2013). This model has three stages i.e. glancing, scanning and decision-making. The recognition of objects and locations (targets) within the visual field is the first stage, and is influenced by individual differences, such as experience and practice. Once a target has been identified the second stage takes over, and the athlete pays more attention to the detail of the object or location (Schuster et al., 2013). The decision is made on how to act in the third stage of the model (Kundel, Nodine, Conant, & Weinstein, 2007; Nodine, Mello-Thoms, Kundel, & Weinstein, 2002).

In 2003, Tenebaum put forward another model which suggests that athletes control their gaze with two distinct of visual search strategies. These strategies depend on the level of the athlete i.e. expert and novice. For instance, when expert athletes identify a relevant cue within the environment, they maintain a fixation on this cue in the centre of their visual display and the peripheral cues are perceived as larger chunks of information (Tenenbaum, 2003). In other words, expert athletes can fixate on one critical location (relevant cue), but due to their knowledge and experience are able to determine what is happening around them as well. In contrast novice athletes direct their visual search to many different target locations within the visual display, i.e. they fixate on many more cues. This type of visual search is referred to as target controlled and is considered to be less effective. The reason for this may be because the athlete spends more time moving from location to location rather than gathering information from one critical location. Tenebaum (2003) also suggests that expert athletes are more successful as they are more accurately able to identify the pattern of the situation compared to novices whose gaze shifts from one location to another.

As alluded to in the previous sections, research has indicated that expert, near-expert and novice athletes follow different visual search strategies and thus gain different information from the environment. More specifically expert athletes tend to demonstrate better perceptual expertise than their lesser skilled counterparts, which may be attributed to their visual anticipatory skills (van der Kamp et al., 2008). However before reviewing the visual search strategies between more skilled compared to lesser skilled athletes, it is important to take note that visual information may be processed differently depending on the action requirements and the goals of the athlete (van der Kamp et al., 2008).

In 1995, Milner and Goodale proposed that visual anticipation relies on two distinct visual systems i.e. the ventral and dorsal. Even though these two systems do not function in isolation, the main distinction between the two systems is that the ventral system predominantly provides information on what action the situation affords (‘vision for perception’) and the dorsal system visually guides the goal-directed movement (‘vision for action’) (van der Kamp et al., 2008). In sailing, for instance, the ventral system would perceive and gain knowledge about objects (e.g. the mark), events (e.g. an opponent approaching) as well as conditions (e.g. wind) and locations during a race that would direct the sailors actions; whereas the dorsal system controls the execution of the movements i.e. hiking when sailing to windward. In other words these two quasi-independent visual systems both contribute to the movement execution. Sailors that attend to specific relevant cues, which will allow them to select the appropriate movement, would predominantly rely on the ventral system. Seeing as the ventral system is primarily responsible to attend and identify knowledge within the visual array, which identifies opportunities for actions (affordances) (van der Kamp et al.; 2008; David et al., 2005). According to the ‘*Visual Anticipation Model’* suggested by van der Kamp et al. (2008), most studies, as a result of the methodology, have investigated the ventral system more so than the dorsal system, however this model suggest that there is a dynamic interaction between these two systems.

While the visual search strategies used by athletes have been researched in a range of sports, such as basketball (Uchida, Mizuguchi, Honda, & Kanosue, 2013; de Oliveria, Oudejans, & Beek, 2007, Vickers, 1996), squash (Abernethy, 1990a; Abernethy, 1990b), biathlon (Vickers & Williams, 2007), ice hockey (Martell & Vickers, 2004), judo (Piras et al., 2014b), tennis (Shim, Chow, Carlton, & Chae, 2005; Singer et al., 1998), golf (Vine & Wilson, 2010), cricket (Sarpeshkar & Mann, 2011; Land & McLeod, 2000), cycling (Vansteenkiste et al., 2014; Vansteenkiste, Zeuwts, Cardon, Philippaerts, & Lenoir, 2013; Wilkie, Wann, & Allison, 2008), soccer (Wood & Wilson, 2012; Piras & Vickers, 2011; Williams & Davids, 1998; Williams, Davids, Burwitz, & Williams, 1994b), baseball (Takeuchi & Inomata, 2009; Kato & Fukuda, 2002), volleyball (Piras et al., 2014a) and speed-skating (Vickers, 2006); there is little information available concerning the visual search strategies employed by sailors either during a simulation or in-situ. More recently, a few of studies have analysed how sailors control their boat as well as what they focus on in order to help determine their decision-making skills. With specific focus on the pre-start period (Araújo et al., 2014), visual behaviour patterns of young sailors during a simulated navigation (Manzanares et al., 2015) and the windward mark rounding (Pluijms et al., 2014; Pluijms et al., 2013).

Existing research indicates that highly skilled athletes typically exhibit different visual search strategies in comparison to less skilled athletes. Specifically research have found that expert athletes have learnt to select the most important and relevant information from their performance context to inform their decisions; consequently affecting their movement behaviour (MB) (Williams & Davids, 1998). Bard, Fleury, and Goulet (1994) reviewed a number of studies looking at the visual search differences between expert and novice athletes. They found that regardless of the sport, the more skilled athletes were able to identify and capture relevant information from within the environment which may not seem relevant to a novice or even intermediate athletes. Williams and Davids (1998) support this by showing that expert soccer players have a more efficient visual search strategy compared to their less expert counterparts, in other words they are more economical with their gaze and thus do not waste as much time focusing on irrelevant cues. Later Vickers, Rodrigues, and Edworthy (2000) found that expert dart throwers can direct their gaze at the most important objects and locations in the environment, at the best possible time in order to perceive and attend to the most relevant cues required for optimal performance. It has been demonstrated that expert athletes select, process and retrieve information specific to the discipline differently when compared to near-expert or novice athletes in the sport (Baker, Cote, & Abernethy, 2002). Craig and Watson (2011) suggest is that the amount and type of knowledge athletes possess and how they process the available information is vastly different when comparing expert and near-expert athletes in the same sport. Furthermore, Vickers (2009) explains that to describe the perceptual-cognitive processes of successful and unsuccessful performances, it is important to determine the visual search strategies utilize by athletes during both successful and unsuccessful attempts at a skill.

It has been suggested that an athlete’s ability to identify when an action can be carried out or not is very important to achieve success (Pluijms et al., 2013). Pluijms et al. (2013) suggest that this is especially critical during a sailing race as there are so many variables to take into account in order to take the optimal route from start to finish. Craig and Watson (2011) also explains that a decision, as a result of recognizing an opportunity to act in the performance context at any one time during the event, depends on the particular environment at that moment in time and whether the athletes believe they are capable of performing the action or not. A study by Savelsbergh, Onrust, Rouwenhorst, & van der Kamp (2006) showed that expert football (soccer) players have developed sport specific knowledge that allows them to recognize a situation and make associations in order to respond in the most appropriate manner possible. As a result it is not only the individual’s ability to identify the correct visual cues but also how the individual uses the available information (Savelsbergh et al., 2006). Perry and Williams (1998) found that expert tennis players displayed significantly higher levels of self-confidence when compared to athletes with less skill. This is in line with research on gymnasts (Bejek & Hagyet, 1996) and swimmers (Jones, Hanton, & Swain, 1994).

Some visual search research has found that highly skilled athletes demonstrate fewer fixations in their environment for a longer period of time compared to less skilled athletes (Afonso et al., 2012; Piras, Lobietti & Squatrito, 2010; Dicks et al., 2009; Mann et al., 2007; Huys & Beeks, 2002; Savelsbergh et al., 2002; Rodrigues, Vickers, & Willimas, 2002; Singer et al., 1998; Ripoll, Kerlizin, Stein, & Reine, 1995; Helsen & Pauwels, 1993). One possible reason for the different visual search strategies among various skilled athletes could be based on the perceived importance of the cues in the performance context, as well as the usefulness of the cue as a simple decision or problem solving strategy for future movements (Piras et al., 2014b; Schuster et al., 2013). This explanation is in agreement with earlier researchers' findings as indicated previously in this section. Accordingly experts' greater anticipatory skills and selective use of information may be attributed to their ability to extract better quality information per fixation and to acquire information more effectively via their peripheral vision (Piras et al., 2014b). This would then explain the fewer fixations and longer durations in experts. On the contrary lesser skilled athletes cannot distinguish between task relevant and irrelevant cues and may miss a critical target or fixate on a distracting object instead; therefore they tend to demonstrate more fixations of a shorter duration that are erratic (Piras et al., 2014b; Schuster et al., 2013).

However there is some disagreement in that other researchers (Roca et al., 2011; Konstantopoulos, 2009; North et al., 2009; Williams & Davids, 1998; Williams et al., 1994b) suggested that more highly proficient athletes have a greater number of visual fixations with shorter duration compared to less skilled athletes. Piras et al. (2014a) accredit this opposite finding to a LTM hypothesis which maintains that expert athletes can encode and retrieve information more efficiently from the LTM than novices, since the experts have gained sport-specific knowledge through practice and therefore exhibit shorter fixations durations.

Vicker's (2007) reviewed the four factors that influence visual search behaviour i.e. the visuomotor workspaces (VMW), the types of objects and locations which are fixated on, the critical cues and the gaze-action coupling. The number of VMW relates to the number of spatial environment within which objects and locations exist that direct the athlete's gaze and attention and which result in the execution of specific goal-directed actions (Vickers, 2007). In short it is the actual visual field(s) environments within which the athlete can find relevant cues that influence the decisions made. Depending on the nature of the sport, athletes often have more than one VMW which exists around them. Generally, this number of VMW increases as the complexity and overall objectives of the sport increase (Vickers, 2007). Sailing is a complex tactical task and would therefore involve more than one VMW. In addition, the number and types of objects (i.e. moving items) and locations (i.e. spatial and stationary aspects in the environment) which are fixated on within the VMW influences the visual search strategy of the athlete. Vickers (2007) explains that objects or locations range from simple single targets to complex multi-targets and whole fields of play. Once again, the more complex the object or location the more challenging it is for the individual's visual search attention and motor system (Vickers, 2007). The third influence on visual search is the critical or relevant cues within the VMW, i.e. the relevant objects or locations at that moment in time for the task which the athlete attends to and directs his/her action. This factor refers to the act of extracting and processing high-priority information in the visual field. The Quiet Eye, often referred to in visual search research, is an example of relevant cues. The final factor is the gaze-action coupling or optimal timing in identifying the critical cues for the necessary action or phase of movement. Vickers et al. (2000) suggests that it is not just about knowing where for look and for how long, but is the ability of the individual to focus on the right object or location at the right time.

2.4.2 Visual Search Strategies in Sailing

As mentioned in the previous section, sailing involves predominantly tactical locomotion tasks. A tactical task is the process of producing a solution through the organisation of forces or objects in a variety of ways within the athlete's environment to achieve an immediate or overall goal (Memmert, 2015; Memmert & Roth, 2007; Vickers, 2007). Most tactical tasks require prior planning and practice of these manoeuvres within the environment as they may take place in a real game or race. In order to successfully achieve their goals during tactical tasks, athletes are required to control their visual search and attention over multiple VMW and identify the most relevant and important cues. During locomotion tasks the athletes experience a constant change in the visual field as they move through their environment; Gibson (1979) refers to this as a change in optic array. In other words, sailors would need to attend to a number of visual objects and locations in order to navigate their way through the environment safely and in some cases as fast as possible.

Visual search strategies during tactical tasks involve a pattern recognition component within the tasks. In other words athletes are required to read and understand patterns of moving objects found in the environment during locomotion over and around objects and locations (Vickers, 2007). So basically, the athletes fixate on or track patterns of moving objects that contain expectancies, relevant cues, plausible goals and actions. The ability to recognise or read the patterns within the environment and act on the information to achieve the goal is also known as visual-spatial intelligence. The visual-spatial intelligence is specifically useful in sailing as the athletes are required to identify and navigate the best route around the course during a race. The sailors are able to identify a possible tactical advantage and place their boat in a position on the race course where they are most likely to gain an advantage over their opponents.

Research on locomotion through a cluttered environment suggests that people may fixate on an object just prior to avoiding it and that they also rely on peripheral vision if the task demands fixation of other objects in the environment (Hollands, Patla, & Vickers, 2002; Patla & Vickers, 1997). In other words during locomotion athletes rely on their peripheral vision to navigate the environment. Patla and Vickers (1997) suggest that when moving through the environment an individual uses travel fixations 60% of the time and only fixate on an object when a challenge arises. Travel fixations are defined as the fixations individuals use in order to continuously monitor the optic flow and accordingly orient themselves in the environment (Vickers, 2007; Patla & Vickers, 1997).

Matthis and Fajen (2014) suggest that when an individual is walking forward their movement is directed in an anticipatory manner that relies on prospective optic flow information. Optic flow refers to how the distribution of light energy reflects off environmental surfaces and how this changes as the individual moves through the environment (Craig & Watson, 2011). The optic flow allows the individual to determine forward motion and the rate an object or location is approaching. As Craig and Watson (2011) as well as Matthis and Fajen (2014) suggest optic flow represents a change over time through the environment and can give the individual predictive information. Consequently, not only helping to make a decision on which action to perform but also when to perform this action (Craig & Watson, 2011). This means that as individuals move through their environment, their locomotion is continuously regulated by visual information (Hollands, Patla, & Vickers, 2002; Patla & Vickers, 1997). The same concept can be applied when an individual is on a boat; in order to successfully manoeuvre the boat through the environment the helm needs to continuously be taking in visual cues and information. An example from sailing would be that the sailors see a gust of wind approaching their boat; they then know that they should change the approach angle of the boat or adjust the trim of the sails. If the angle of the approaching gust is very different they may decide to tack.

Lee (1976) identified Tau as an optic variable, which identifies time to contact. Tau gives information to individuals about an object or location prior to it reaching them; in order for the individuals to perform an appropriate action (Craig & Watson, 2011). In all tactical sports, parameters within the environment are more than likely always changing, thus if individuals can use Tau while gathering information they may be able to identify what will happen in future situations.

In sailing or any locomotion tasks the athlete often has to decide between path alternatives at certain junctions. Due to the fact that the sailors can take any path to get to the marks, these junctions may be different for every competitor. They also differ depending on the environment, position of competitors and location of next mark. In order for sailors to choose a successful path around the course, they need to take into account any predictive information of where the wind will be, how strong the gusts are and the angle of the gusts relative to the constant wind angle, the angle of the boat and the angle and distance to the next mark. They need to manipulate the boat to the correct position, i.e. heel, angle to the wind and sail settings by exploiting the relationship between the visual information gained and the required movement. And finally, they need to base their actions and decisions on prior knowledge or experience in order to supplement any inadequate visual information (Regan et al., 1997).

Limited studies have specifically set out to investigate visual search strategies in sailors. In 2013, Pluijms et al. presented a review comparing laboratory and field experiments on how perceptual-motor skills are performed in the different scenarios. The researchers used an example in sailing by conducting a case study which presented the possible performance variables one can analyse i.e. visual search behaviour of the sailor, MB of the sailor, as well as recording the environmental conditions and boat performance during a windward mark rounding. Their reason for following this approach was to simulate the performance environment the sailor would normally find themselves in during a race and identify their behaviour during the task with advanced technologies. They concluded that it is possible to identify the necessary points during a live situation, even in a dynamic sport such as sailing.

In 2014, Pluijms et al. pursued their interest in in-situ experiments. In this investigation they used their findings from the previous case study and subsequently set out to identify the key-performance cues in sailing and to what degree these contribute to skilled performance. Fourteen expert and near-expert sailors took part in the study and as a group completed sixty-two windward mark roundings with no involvement from other competitors and an additional forty windward mark roundings against competitors. The researchers concluded that all four variables i.e. visual search behaviour, MB, boat control and environmental conditions, relate to sailing performance in various degrees (Pluijms et al., 2014). Results were similar to those found by studies involving locomotion around a corner (Kandil, Rotter, & Lappe, 2010; Vickers, 2006), in that they indicated better mark rounding manoeuvers were related to looking more at the tangent point during the actual rounding. Results also indicated that skilled performance without opponents showed the sailors looking outside the boat more often, suggesting that they search for relevant information outside the boat during the mark rounding; while skilled performance with opponents showed the sailors looking inside the boat more often, i.e. at locations on their deck or sail, and moving between fixation locations less frequently.

Sailing around a race course and more specifically the windward mark rounding of the course is comparable to research that investigated visual search strategies while driving a car and in speedskaters (Kandil et al., 2010; Vickers, 2006). Various researchers have investigated the visual search strategies employed while driving a car (Kandil et al., 2010; Mestre et al., 2005; Mestre & Durand, 2001; Land & Lee, 1995). These researchers found that the critical or relevant cue fixated on when navigating turns is the tangent point within the turn. The tangent is a single point found half way on the inside of the turn. Mestre and Durand (2001) suggest that the final fixation to the tangent point of a turn is critical, as this point provides relevant information required to navigate the turn safely at high speeds. In 2005, these results were confirmed in further research by Mestre et al.

Speedskating is a high-pressure sport and the athletes are often required to make many tactical decisions in a very limited amount of time. For example, the athletes are required to start without fault and maintain skating speeds as fast as 40Km/h, while at the same time navigating their way around the track. The difference in the way expert and near-expert athletes view and interpret the same environment is however significant (Vickers, 2006). In 2006, Vickers published a study on five expert speedskaters. Vickers (2006) suggested that in speedskating, like driving, the critical cue to fixate on prior to navigating the turn is the apex or tangent point of the corner. The results showed that expert speedskaters directed their gaze 86% of the time to the apex of the turn, compared to near-expert which showed only 60% at this location (Vickers 2006). The author concluded that the most important factor in maintaining speed through the turn was fixating the gaze on the tangent point of the turn and the longer the athletes could do this the better their performance (Vickers, 2006).

An investigation by Manzanares et al. (2015) identified the visual search strategies employed by twenty junior sailors from the Optimist dinghy class. Ten sailors formed the top of the ranking ladder, while the other ten were ranked at the bottom. Each sailor was required to complete a simulated sailing regatta start using a virtual sail simulator in a laboratory. Participants had five opponents during the simulation. During the simulation their visual search was recorded, with the overall goal of determining the sailors' fixation sequence while they chose where they wanted to position their boat for the start. The results showed that the top ranking sailors used a wider visual pattern more often compared to the bottom ranked group. They suggest that this is in line with González and Casáis (2011), in that the more experienced athletes are able to use their peripheral vision more effectively and as a result detect critical cues or movements from further away. The researchers concluded that top ranked junior sailors follow a random pattern of visual fixations i.e. they do not follow a sequence; unlike their bottom ranked counterparts whose visual pattern centred on two fixation locations (wind direction and other). They suggest that the top ranking sailors' random pattern may be more successful due to the fact that they have a higher chance of adapting to any changes within the environment (Manzanares et al., 2015).

2.4.3 Visual Search Criticism

Pomplum et al. (2001) suggest a few criticisms to the research and testing methods of visual search strategies. The first being that the testing of the visual search strategies employed by many athletes show only the pathway taken by the individuals to find a target in their visual field. Also that it is impossible to identify the hypothesized difference between two consecutive stages of individuals' visual search strategies through testing eye movements alone (Pomplum et al., 2001). The researchers also state that the research on visual search strategy to date has neglected the critical element of memory. It is necessary that the individuals hold some representation of the task in memory in order to recognize the critical target within the situation among all the other distractors. In other words they need an idea of what characteristics they are looking for to identify the target within the actual situation (Pomplun et al., 2001).

2.5 Executive functions and Decision-making

Executive functions (EF) have been described as an umbrella term for higher-order cognitive functions such as planning, prioritising, set-shifting, organising, WM, mental flexibility, sustained and selective attention, multitasking, conflict resolution, controlling emotional reactions and resistance to interference as well as decision-making (Buelow, Okdie, & Cooper, 2015; Swami, 2013; Chan, Shum, Toulopoulou, & Chen, 2008). Vestberg et al. (2012) suggest that EFs are important when an athlete captures information and subsequently sorts through it in order to make a decision (Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012).

In order to organise EFs we adopt the three-factor framework proposed by Diamond (2013). Diamond (2013) refers to three core components, specifically inhibitory control (IC), WM and cognitive flexibility (CF) of EF which have been described as necessary in a sporting context. These three components work together resulting in the influence of higher-order functioning, such as decision-making (Buelow et al., 2015; Diamond, 2013). Firstly Diamond (2013) addresses IC, which is an athlete’s ability to change their idea and subsequently adapt to the situation, i.e. they are always evolving and changing their thought processes. In addition, motor response/inhibition may possibly play an important role in sailing as motor actions must frequently be inhibited when the conditions on the race course changes rapidly (Voss, Kramer, Basak, Prakash, & Roberts, 2010). The researcher identifies WM as the second component. WM makes it possible to adapt to a changing stimulus, allows time to consider what to do next and meet the performance-goals (Verburgh, Scherder, van Lange, & Oosterlaan, 2014; Swami, 2013). Diamond (2013) refers to CF as the third component of EF. An individual with high levels of CF are more easily able to adjust to changing criteria.

Previous research has shown how physical activity improves cognitive function (Jacobson & Matthaeus, 2014) and that EF have been suggested as being important for success in sport (Verburgh et al., 2014). An investigation by Vestberg et al. (2012) found that expert soccer players performed with higher proficiency on executive functions tasks, specifically concerning general executive functions such as planning, attention, cognitive inhibition and WM. Verburgh et al. (2014) further indicated that EF are needed in sports such as sailing in order to anticipate events, to adapt to a constantly changing environment as well as for recalling race strategies.

The three components, according to Diamond’s model (2013) have been referred to as the “cold” components of an individual’s EF as they often do not arouse much emotion and have been described as being “mechanistic” or “logically” based (Chan et al., 2008; Grafman & Litvan, 1999). Executive functions comprises a succession of these cognitive functions put together to achieve an end goal (Stuss et al., 2005; Damasio, 1995). The cold functions are more recently being researched with the focused on determining the relationship between acute exercise, training and cognition or EF (Pesce, 2012). Jacobson and Matthaeus (2014) found that athletes scored higher on some of the EF tasks than non-athletes, and that these scores varied based on sport type. More and more evidence is recognising that that individuals who partake in regular physical activity show an improvement on executive tasks (Boucard et al., 2012; Predovan, Fraser, Renaud, & Bherer, 2012; Colcombe & Kramer, 2003) and a delay in their cognitive decline (Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008; McAuley, Kramer, & Colcombe, 2004).

The EF components which have been specifically looked at previously from a sporting context include problem solving, cognitive inhibition, WM (STM), and attentional focusing (Jacobson & Matthaeus, 2014; Verburgh et al., 2014; Alves et al., 2013; Vestberg et al., 2012; Voss et al., 2010). All of these concepts are important in sailing since they enable the sailor to determine the optimal route to sail to the next mark. For example excellent attentional focus may be required in order to gather information from areas surrounding the individual’s boat and in spaces where wind shifts may occur, the sailors also need to anticipate the behaviours of their opponents and environmental conditions such as the waves (Verburgh et al., 2014).

Research on other sporting modalities, besides sailing, has suggested that athletes’ visual search strategies may influence the quality of their decision-making ability (Ripoll et al., 1995). This in addition relates to Araújo et al. (2005) description of decision-making in sailing (based on the EAT) as non-linear cumulative effects of exploring and using informational constraints in a race which depends on the harmonious relationship between the sailor and sport-specific information in the environment. Decision-making is the process of assessing a number of available options and subsequently choosing among these alternatives in order to achieve a goal (Buelow et al., 2015; Swami, 2013). As a result an individual can achieve success if they consider all the options and select the logical choice; in a sporting context the output of this choice is an action (Reason, 1990).

In 2005, Araújo et al. published a study aimed at determining the effect expertise has on decision-making skills in sailors. Thirty five sailors (average age 23.1 ± 4.8 years) were divided into three skill groups (expert, skilled and intermediate); while a non-sailor group consisted of 23 individuals (average age 22.2 ± 2.1 years). The participants were required to race three races in a computer simulated regatta, with the goal of arriving at the finish line ahead of their respective opponents. They controlled their boat using four keys on a keyboard, while verbalising their thought processes and any reasons for the decision previously made or action about to be made. The researchers categorised the verbalisations into four groups: 1) adversary, about their opponent; 2) spatial, about their position relative to their opponents; 3) manoeuvres; 4) wind direction or speed. An analysis revealed that each group of sailors used the available information differently in terms of attendance to critical information; which in turn affected the actions they chose to perform. Furthermore, the expert sailors identified the most relevant sources of information, such as the wind information, more often when compared to the other groups. The researchers concluded that the decision-making process in sailing is dependent on the sailors' skill to explore and use the informational constraints in the race, and that their familiarization to important cues is developed with expertise.

A more recent study by Araújo et al. (2014) again looked at the decision-making skills of sailors; however in this case the focus was only on the pre-start and start of the race. Fifteen junior sailors (average age 12.1 years; SD = 1.6) participated and were required to complete two real-world match races against an opponent of equal skill level. A retrospective verbal protocol was used in order to determine the thought patterns of the sailors. The researchers suggest that based on the results of the study, junior sailors should act when something happens in front of them rather than memorizing actions or strategies. They concluded that the sailors' decisions were influenced by the environment and their competitor, which revealed that the sailors displayed emergent decision-making behaviours. This emphasizes the importance of exceptional executive functions, such as IC and CF, which would allow expert sailors to reactively adapt to their ever-changing environment to make the most appropriate decision.

A sporting event induces stress and as a result stress is felt by every level of athlete, be it someone doing something for the first time at school or an expert athlete performing at the Olympics (Calmeiro, Tenenbaum, & Eccles, 2014). Stress can be conceptualized as a dynamic process, in that the athletes interact with their environment which in turn may cause them to develop a perception of the situation. As a result the stress an athlete may feel is usually created by the athlete (Pensgaard & Ursin, 1998). Stress compromises executive functions, especially WM which in turn may reduce decision-making skills (Preston, Stansfield, Buchanan, & Bechara, 2007). Preston et al. (2007) suggest that the relationship between stress and the athlete's decision-making skills is complex and dependent on the task requirements and the athlete.

Failure on an EF test may be due to damage in the individual's cognitive functioning processes (Chan et al., 2008). However, one must keep in mind that an individuals' performance on an EF test does not give us an indication of how they may achieve in a different test, or subsequently in a real-world situation (Chaytor, Schmitter-Edgecombe, & Burr, 2006; Burgess, Alderman, Evans, Emslie, & Wilson, 1998; Burgess, 1997). This may be due to the fact that the conditions are too artificial, not situation specific, or the individual is stressed as a consequence of being evaluated. As a result the more recent tests have been developed with an emphasis on incorporating more complex and life-like situations, for example tasks that challenge a number of the cognitive functioning processes at the same time (Shallice & Burgess, 1991). We need to consider that although an individual may not excel in an EF test, does not necessarily mean that they cannot function in their typical everyday activities. It may be an indication that the environment within which they interact places little demand on the skill being tested (Chaytor et al., 2006).

To the researchers knowledge no study to date has focused on the executive functions of sailors, in either generic or sport-specific tests.

2.6 Problem Statement

Minimal differences in physical characteristics and skill-level differentiate between expert sailors. Consequently, this cross-sectional observational descriptive study may provide information about the inherently occurring behaviours, approaches or other characteristics by identifying performance differences between national-level sailors' visual perceptual skills and/or executive functions. Therefore possibly isolating perceptual skills required by these sailors and thus provide an opportunity for further research in training techniques of these skills.

To date very little research has been done on visual search strategies (Manzanares et al., 2015; Pluijms et al., 2014; Pluijms et al., 2013) as well as decision-making in sailing (Araújo et al., 2013, Araújo et al., 2010; Araújo et al., 2005) and none on executive functions skills of sailors. This translates into restricted knowledge regarding performance enhancement and possible training techniques in sailing. The current research may highlight the most important relevant cues used in simulated races and how these relate to their decision-making skills.

Therefore the purpose of the current research is to contribute to the literature describing the visual search strategies sailors employ. The application of this information is valuable to sailors and coaches, respectively. We hope to provide insights into the perceptual skills of sailors and the important executive functions skills they possess, which may help to enhance performance of novice and near-expert sailors by giving them the competence to make better decisions in future races. Furthermore, this is a preliminary investigation subsequently future studies could expand on these topics and use the information for possible talent identification purposes.

2.5.1 Research Aim

The aim of this investigation was two-fold, to describe the visual search strategies and executive functions of expert South African sailors.

To answer this research question the following research objectives were determined:

1. To identify the visual search strategies employed by sailors during simulated races, using Radio Controlled Lasers (RCL) and a Computer Simulation (Tactical Sailing©), specifically the fixation locations, search rate including the total number of fixations, average fixation duration, and fixation frequency (fixations per second); and the percentage viewing time in different identified fixation locations. [Article 1 and 2]
2. To determine if a relationship exist between performance and visual search strategies employed by sailors during a simulation. [Article 1 and 2]
3. To identify the executive functions, i.e. inhibitory control, working memory and cognitive flexibility, implemented by sailors. [Article 3]
4. To establish if a relationship between the sailing performance level, role and executive functioning exist. [Article 3]

Variables

- <u>Independent variables:</u>
    - Simulated races
        - RCL simulation
        - Computer simulation
    - Performance level
        - Professional sailing history
        - Simulation race success rate
- <u>Dependent variables:</u>
  Event duration
  Visual search strategy
    - Fixation locations
    - Search rate including total number of fixations, average fixation duration and fixation frequency

Percentage viewing time

Executive functions

Inhibitory control

Working memory

Cognitive flexibility

- Categorical variables:

  Age, gender, BMI, sailing class (Dinghy, Keelboat, Multihull), professional sailing history years, success rate, role

- Confounding variables:

  Depression, anxiety, cognitive impairment, education

CHAPTER 3

ARTICLE 1

Visual Search Strategies during a Computer Simulated Event in Sailing

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ABSTRACT

The visual search strategies employed by sailors during a race has been identified as a determining factor in the successful identification and interpretation of relevant information from the environment. The aim of this research was to determine the visual search strategies sailors employ during a computer simulated race. The event consisted of three computer simulated races. The visual search variables in question included the search rate (total number of fixations, average fixation duration, and fixation frequency) and the percentage viewing time in each fixation location. The results showed that the successful sailors had fewer fixations of longer durations and spent more time looking at their boat and wind markers compared to the unsuccessful sailors. This suggests that in order to be a successful sailor one must be able to read and understand the wind conditions and the effect of the environment on the boat.

Key words: Visual Search Strategy, Sailing, Computer Simulation

3.1 INTRODUCTION

Sailing is predominantly controlled by the environment [1] and is categorised as a dynamic, tactical and open skill sport. The sailors are required to make decisions based on their immediate environment, for example the wind, waves and their opponents. While at the same time they also have to consider the fastest track to get around the course, with the overall performance goal of reaching the finish line before their opponents [2]. As a result, the information they gain can be used in the immediate moment or later in the race. All of these abovementioned elements, which the sailors have to take into account, are unstable and consequently very difficult to control [3].

Prior research in sailing has identified specific performance capabilities necessary for success within the sport i.e. physical fitness, boat speed, tactical intelligence or successfully reading the environmental conditions and adapting to them, physiological and physical skills, boat handling techniques, injuries and experience [4-6].

More recent research focuses more on the perceptual-cognitive skills of sailing, specifically how sailors gain information during an action or a race which assist sailors in making race-winning decisions [3, 4, 7]. Decisions typically involve where to position the boat on the course in order to best exploit the environmental constraints to successfully achieve their main performance goal [2]. Araújo and colleagues [2] suggest that sailors are able to make tactical decisions in advance; however they also need to consider and interact with their opponents, who may change course at any time and the ever-changing environmental conditions. They also suggest that there is a need to understand the nature of how the sailors are able to arrive at a decision through their information seeking processes and how this affects their strategic choices during a race [2]. Kirlik [8] stated that the active exploration of the immediate environment surrounding the athlete is a fundamental part of solving a problem and subsequently making correct decisions.

In order to gain the necessary information for decision-making, sailing requires a vast amount of exploration of the surrounding environment. This exploration can come from a variety of senses i.e. cutaneous [9] and visual feedback [3, 4]. Visual search strategies in sailors have been investigated by previous researchers who have identified critical cues that sailors have deemed the most relevant [3, 4]. Once sailors are able to determine where to look for the most relevant information, they will gain an advantage as they can anticipate what the wave ahead of them may do or where their opponent may go. Therefore information gained from the visual search strategies employed by sailors is a determining factor in their success due to the nature of the uncontrollable environment [3].

Previous research defines four visual search strategy components, namely 1) the fixation location, which includes the areas in the visual field which indicate the most relevant information for the athlete; 2) the fixation duration at each fixation location, this shows the importance of the fixation location for the athlete; 3) the number of fixations and 4) the sequence of the fixations [10, 11]. Most of the visual search research to date has considered these elements and the results show that differences occur between expert and novice athletes [12-15]. Two different visual search strategies of expert athletes have been reported by research. Mann and colleagues [13] found that expert athletes have fewer fixations for longer durations, while Roca and colleagues' [14] results showed that expert athletes perform more fixations for a shorter time interval. The two schools of thought suggest that either the expert athletes are able to identify the critical cues earlier, thus spend more time gaining information from these; or that expert athletes do not require as much time in each fixation location to gain the necessary information to make a successful decision.

Studying visual search strategies has proven very difficult in environments with a potential for a large amount of glare and other practical challenges, such as the safety of the equipment i.e. getting the eye tracker equipment wet. To the researchers' knowledge only two studies have been able to successfully assess a sailor's visual search strategies in-situ [4, 16]. As a result, most visual search research in sailing and many other sports has involved the use of computer or film-based simulations. Araújo and colleagues [7] suggest that simulations provide the participants with an opportunity to explore the task constraints and look for specific information within an environment similar to one they would find themselves in a real-world setting. Due to the limited number of studies done on determining the visual search strategies of sailors, the visual search pattern remains inconclusive.

The primary aim of this descriptive study was to analyse the visual search strategies, specifically the search rate, which includes the total number of fixations, the average fixation duration and the fixation frequency (fixations/second) [17, 18], and the percentage viewing time to each fixation location, employed by South African sailors during a computer simulation. The secondary aim was to determine how this relates to their sailing history, the success rate during the simulated races and the sailing classes (i.e. Dinghy, Keelboat or Multihull).

3.2 METHOD

SAMPLING AND PARTICIPANTS

This study used a homogenous purposive sampling technique. Twenty four South African sailors, 20 males and 4 females, aged 19 – 50 years (mean = 25.83; SD = 9.36) took part in the study. This study exclusively considered sailors who had competed at a national level (professional sailing experience mean = 14.21 years, SD = 8.38), that is they had competed in at least one South African national event during the last three years. Participants unfamiliar with computers and with any visual impairment that could not be corrected, e.g. colour blindness, were excluded. Participants were recruited via personal involvement, social media and word of mouth. Ethical clearance was approved by Research Ethics Committee (HS1033/2014), with all participants providing informed consent and fulfilling all inclusion criteria prior to participation.

INSTRUMENTS

Participants performed three races with one opponent on a computer simulation by Tactical Sailing® software (ViSdP & TDG, Munich, Germany). The computer simulation was projected by an overhead projector onto a (3.95m x 2.80m) white screen placed 3 meters in front of the participant. The experimental set-up is illustrated in Figure 3.1.

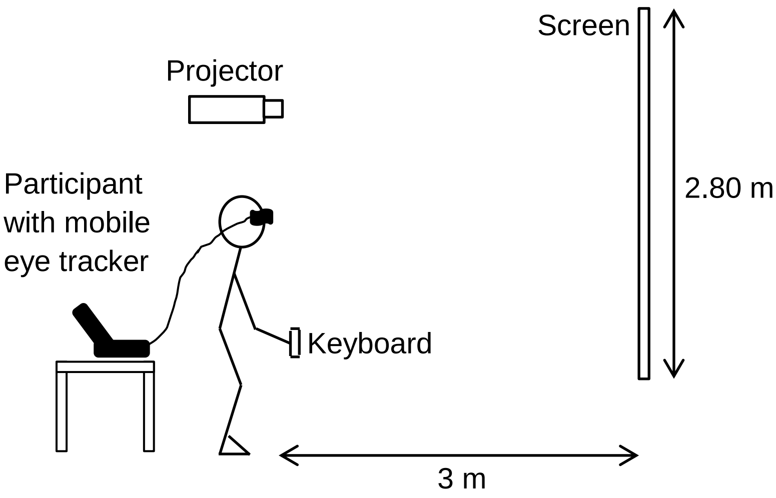

Figure 3.1 Lateral View of the Experimental Set-up

The simulated racing course is illustrated in Figure 3.2. All participants were familiar with computers but unfamiliar with the specific computer simulation used in the study. The simulation showed a bird's-eye view of the course throughout the duration of each race. Even though the simulation is not structurally equal to that of a natural environment, it does allow for similar interaction and gaining of information. For example, the simulation shows the angle of the wind and has areas of more and less wind speeds.

Figure 3.2 Screen Shot taken from the Computer Simulation (Tactical Sailing©)

Visual search strategies were recorded with a mobile eye tracker (30 Hz). The ASL Mobile Eye eye tracker (Applied Science Laboratories (ASL), Bedford, USA) consists of two cameras mounted on a pair of lightweight glasses. The image recorded from the scene camera and the eye cameras are integrated using ASL Results Plus software (Applied Science Laboratories, Bedford, USA) into a single video. This video displays the environment in front of the participant with a superimposed gaze cursor, showing the focus point. The data was collected and analysed by high performance specialists (ICC agreement = 0.979).

PROCEDURE

The study took place at the Sport Science Department (Stellenbosch University, South Africa). Participants received instructions about the experiment and the mobile eye tracker, such as the nature of the test and calibration process for the eye tracker. They also completed a general information questionnaire that included questions about their sailing history. Participants were then required to race three races against one opponent. The participants raced against a sailor of the same performance level (aged 23) who assumed the role of the "opponent" for all of the races.

The participants were first fitted with the eye tracker, which was calibrated using between seven and nine fixed points on the screen. Before each race, calibration was retained by asking the participants to look at specific points on the screen. Prior to the first race, the participants were given no more than 5 minutes to get accustomed to the controls of the boat and the sailing angles. Participants manipulated the direction of their boat using the left and right arrow keys on a keyboard, while the software automatically controlled the sail settings. The goal of a match race is to read the environmental conditions as successfully as possible and use this information to arrive at the finish line ahead of the opponent [7]. This same goal was present in the simulation. For each race, the simulation showed a 90 second count down prior to the start, after the 90 seconds the competitors were free to cross the line between the Committee Boat and the Pin mark. Once the line was crossed the participants were required to race up to the number 1 mark, down to number 2, back up to number 1 and then down to the finish line. The experiment lasted approximately 20 minutes per participant. Participants received feedback about their performance after the experiment was complete.

DATA RECORDINGS

Data recording was initiated as soon as the first competitor crossed the start line and ended as soon as the participant crossed the finish line. Thus, the length of the race was determined by how long it took for the participant to complete the course. Hence the time it took to complete the course was recorded, as well as the result of the race (won/lost).

In order to assess the visual search strategies of the sailors during the simulation, the search rate (total number of fixations, average fixation duration and fixation frequency (fixations/second)), as well as the percentage viewing time in the fixation locations were recorded for each race. The percentage viewing time concerns the sum of all the fixations in one fixation location [19]. Four fixation locations were defined using the visual search video data (ASL Results Plus®). For every frame per second, direction of the gaze was categorised as locations i.e. BOAT (the sailors boat they manipulated), OPPONENT (the boat the researcher manipulated), MARKS, WIND (indicators on the screen) and OTHER (any fixation not in the pre-determined 4 fixation locations). As a result the visual search measurements included the mean percentage viewing time (i.e. percentage viewing time) in the identified fixation locations. Fixations were determined when the gaze was located on a single point within 3° of visual angle for a minimum duration of 3 frames or 120 ms [20].

STATISTICAL ANALYSIS

Statistical analysis was done using Microsoft Office Excel (Windows® 2010, USA) and XLSTAT® add-in. Descriptive data was reported as mean ($\bar{x}$), standard deviation (SD), percentages (%) and frequency distributions. Data was first analysed for the group as a whole, then based on sailing history rank, success rate during the simulation, as well as class of boat. Shapiro-Wilks test for normality was performed and based on the findings a Kruskal-Wallis test was used to compare the percentage viewing time for each fixation location, with a pair-wise Bonferroni correction. A Spearman's Rank correlation was used to assess the relationship between the sailor's history rank and the visual search variables. For parametric data, independent t-tests (with pair-wise Fisher LSD corrections) were used to analyse any differences between groups (i.e. successful and unsuccessful) within the visual search variables and subsequent fixation locations. For non-parametric data, Mann-Whitney tests (with pair-wise Bonferroni corrections) were used to identify any differences between the groups. Alpha level was set at 0.05.

In addition, Cohen's effect sizes (*d*) were calculated in order to establish practical significance for meaningful differences. Interpretation of Cohen was based on 0.20 as small, 0.50 as medium and 0.80 as large effect sizes [21, 22].

3.3 RESULTS

Seventy computer simulation match races performed by twenty four participants were included in the analysis. As a group (n = 24) sailors spent an average of 144.84 seconds (SD = 10.57), completing the simulated race. During this time they fixated an average of 231.03 times (SD = 30.53) which equated to frequency of 1.63 fixations per second (SD = 0.17). The average fixation duration was 0.52 seconds (SD = 0.09). Figure 3.4 summarises the most common fixation locations during all the trials. The percentage viewing time in each fixation location presented in Figure 3.3. A large majority of time was spent fixating the BOAT (46%) and the WIND (24%), while the sailors fixated least on the MARKS (8%) and OTHER (8%).

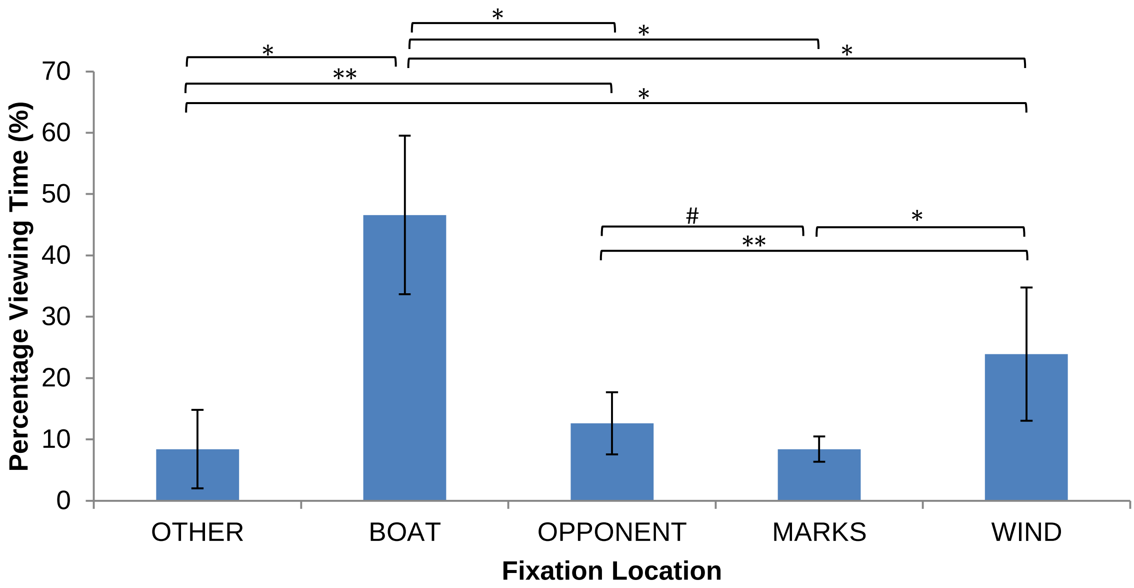

Figure 3.3 Comparison of Percentage Viewing Time in Fixation Locations for the Whole Group

* p ≤ 0.01; ** p ≤ 0.05; # p between 0.06 and 0.09

When the sailors were ranked (top ranking and bottom ranking) based on their professional sailing history as reported in the general information questionnaire, a weak correlation was found when conducting a Spearman Rank Correlation between professional sailing history rank and event duration (rho = -0.13, $p = 0.53$). Additional correlations found no notable relations between the professional sailing history rank and the visual search variables (rho < 0.21). Furthermore, none of the correlations presented statistical significance ($p > 0.05$).

The event duration for the top ranking group ranged from 133.31 – 159.93 seconds, and 127.29 – 164.52 seconds for the bottom ranking group ($p = 0.85$). The difference between the search rate variables and between the two groups failed to reach any level of significance ($p > 0.05$; Table 3.1). Similar as to when all the sailors were grouped together, a majority of time was spent fixating the BOAT and the WIND in both top and bottom ranking sailors (Figure 3.4).

Table 3.1 Comparison of Event Duration and Search Rate for Professional Sailing History Rank (n = 24; $\bar{x}$ ± SD with effect size values (*d*))

Variables	Top Ranking	Bottom Ranking	Effect Sizes	Outcome	p-value
Event Duration (seconds)					
	145.26 ± 8.22	144.42 ± 12.87	0.08	Negligible	0.85
Total Number of Fixations					
	226.77 ± 37.80	235.28 ± 21.94	0.29	Small	0.54
Average Fixation Duration (seconds)					
	0.53 ± 0.10	0.52 ± 0.08	0.05	Negligible	0.91
Frequency (fixation/second)					
	1.62 ± 0.17	1.64 ± 0.18	0.12	Negligible	0.79

No statistical significance was observed in percentage viewing time in the fixation locations between the top and bottom ranking groups (p > 0.05; Figure 3.5). However a medium effect size was observed for percentage viewing time in the OPPONENT location (*d* = 0.72), with the top ranked sailor fixating on the OPPONENT 3% more than the bottom ranked sailors (Figure 3.4).

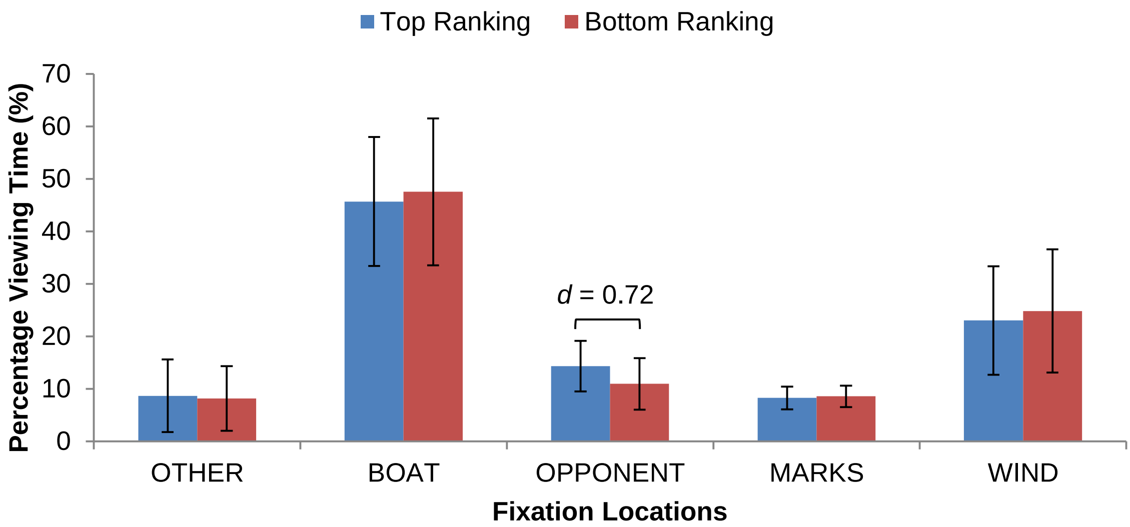

Figure 3.4 Comparison of Percentage Viewing Time in Fixation Locations for the Top and Bottom Ranking Groups

When the participants were grouped according to the result of the computer simulation (i.e. if the participant won or lost the race), a significant difference was found in mean event duration (p < 0.001). In that the successful races ($\bar{x}$ = 138.77, SD = 8.69) were of significant shorter duration compared to the unsuccessful races ($\bar{x}$ = 147.69, SD = 12.69) (Table 3.2). A large effect size supports this (*d* = 0.79). While the successful group ($\bar{x}$ = 219.22, SD = 30.30) performed a significantly fewer number of fixations compared to the unsuccessful group ($\bar{x}$ = 241.85, SD = 32.74) (p = 0.02). In terms of fixation duration, the average fixation duration was significantly longer in the successful group ($\bar{x}$ = 0.57, SD = 0.09) than the unsuccessful group ($\bar{x}$ = 0.51, SD = 0.10) (p = 0.02). Although the difference is not significant, the successful group had a lower frequency of fixations per second when compared to the unsuccessful group (p = 0.20).

Table 3.2 Comparison of Event Duration and Search Rate for Successful and Unsuccessful Groups (n = 24; $\bar{x}$ ± SD with effect size values (*d*))

Variables	Successful	Unsuccessful	Effect Sizes	Outcome	p-value
Event Duration (seconds)					
	138.77 ± 8.69	147.96 ± 12.96*	0.79	Large	0.00
Total Number of Fixations					
	219.22 ± 30.30	241.85 ± 32.74**	0.72	Medium	0.02
Average Fixation Duration (seconds)					
	0.57 ± 0.09	0.51 ± 0.10**	0.59	Medium	0.02
Search Rate (fixation/second)					
	0.58 ± 0.18	1.64 ± 0.01	0.24	Small	0.20

* p ≤ 0.01; ** p ≤ 0.05

Figure 3.5 shows the percentage viewing time between the successful and unsuccessful groups in each fixation location. Significant differences were found between the OPPONENT (Successful = 10% vs. Unsuccessful = 14%) and the WIND indicators (Successful = 30% vs. Unsuccessful = 20%). Success rate affected the percentage viewing time to the OPPONENT (p = 0.02) and to the WIND indicators (p = 0.02). These were supported by a medium effect size in OPPONENT (*d* = 0.67) and a large effect size in WIND (*d* = 0.78). No differences were apparent between the OTHER, BOAT and MARKS locations (p > 0.05).

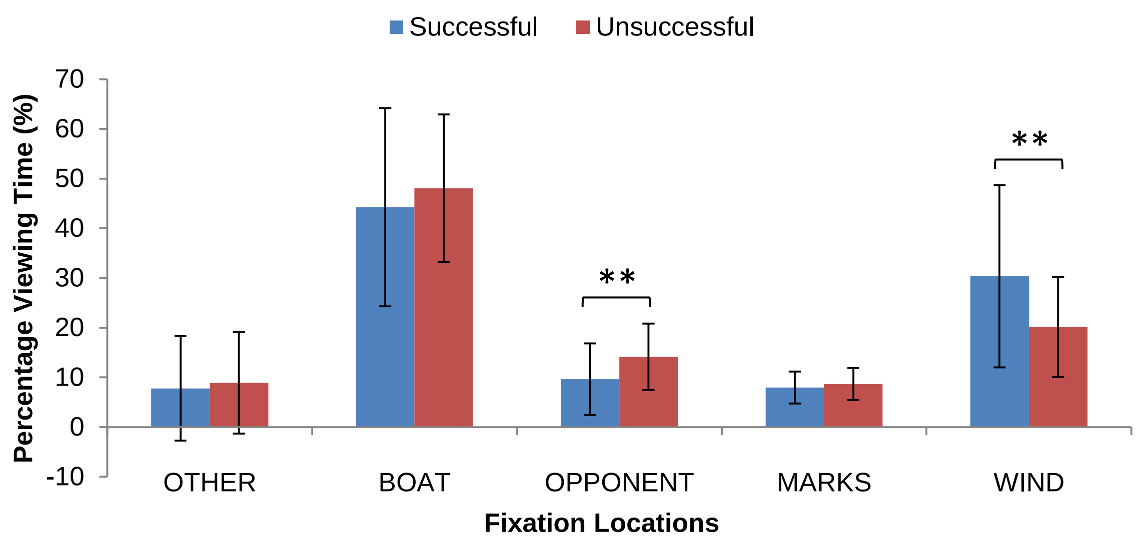

Figure 3.5 Comparison of Percentage Viewing Time in Fixation Locations for the Successful and Unsuccessful Groups. ** $p \leq 0.05$

When analysing the sailors' data according to the primary sailing class in which they compete, specifically Dinghy, Keelboat, and Multihull. No significant differences were found when comparing the search rate variables between the three sailing classes (p > 0.05; Table 3.3).

Table 3.3 Comparison of Event Duration and Search Rate for Sailing Classes (n = 24; $\bar{x} \pm$ SD)

	Dinghy (n = 8)	Keelboat (n = 7)	Multihull (n = 9)	p-value
Variables	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	
Event Duration (seconds)				
	141.88 ± 10.60	145.90 ± 9.16	146.65 ± 12.10	0.64
Total Number of Fixations				
	237.08 ± 16.59	231.66 ± 46.08	225.15 ± 27.77	0.74
Average Fixation Duration (seconds)				
	0.50 ± 0.06	0.50 ± 0.07	0.57 ± 0.11	0.22
Frequency (fixation/second)				
	1.68 ± 0.16	1.68 ± 0.13	1.54 ± 0.19	0.16

A Kruskal-Wallis was completed comparing the percentage viewing time (Figure 3.6) between these three classes (p = 0.01). Further analysis showed that the percentage viewing time of the Keelboat class (17%) to their OPPONENT was statistically significantly more than that of the Multihull class (9%) (p = 0.01). While a weak tendency was seen in the percentage viewing time to the OPPONENT location between the Dinghy (13%) and the Multihull classes (9%) (p = 0.07). No other significant differences were observed in percentage viewing time between the three sailing classes in the fixation locations (*p* > 0.05).

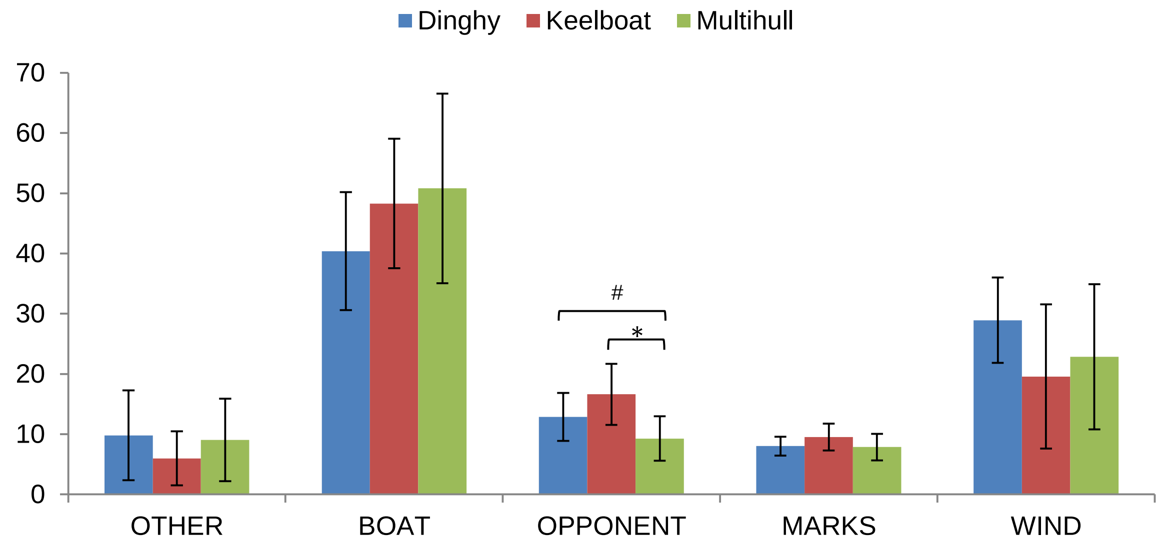

Figure 3.6 Comparison of Percentage Viewing Time in Fixation Locations for the Sailing Classes

* $p \leq 0.01$; # $p = 0.07$

3.4 DISCUSSION

The sailors' ability to detect and interpret wind is crucial in sailing as the speed and angle of the boat relies so much on the wind speed and direction [23]. Thus, the visual search information gained from the present study adds to our understanding of how sailors use their visual system to pick up important information during a race relating to the sailors' boat, the environmental conditions (wind strength and direction), their opponents and the marks. With this in mind, the results do not imply the use of the same strategy in a real-world setting.

This research showed that the sailors identify their boat and the wind location cues to be the most important when racing in a computer simulated event, this is seen by the fact that they spent the majority of the time looking in that area. The reason for these findings may be due to the overall goal of the sailors, i.e. to navigate their boat around the course as fast as possible. With the effect the wind has on the boat, the sailors understandably need to spend time identifying any changes in wind patterns in order to maintain boat speed and angle.

No differences were observed when comparing the sailing history rank to the visual search measurements, nor were any relationship found between the sailing ranking and performance as well as visual search variables. The reason for this may relate to the fact that this is a homogenous group of sailors, i.e. they all compete at the same level of competition regardless of their class of boat or role on the boat.

In keeping with previous research that used success rate of a simulated event, the researchers hypothesized that the successful group will maintain a better visual search pattern compared to their less successful counterparts [24]. The significant difference between race performance of the two groups (i.e. the mean time it took for the groups to finish the race) shows that the successful group, as expected, were much faster at completing the course compared to the unsuccessful group. This clearly shows that they consistently sailed a shorter and faster track around the course. Results found by Araújo and colleagues [7] showed that expert sailors were more successful in the simulated event as they were able to complete the regatta in less time. The search rate analysis revealed that the successful group of sailors performed fewer fixations of longer duration when compared to the unsuccessful group. Similar results were found by a number of studies which compared expert and near-expert or novice athletes [19, 25-28]. This supports the viewpoint which suggests that the successful sailors have a more cost-effective visual search strategy and are subsequently able to extract more task-relevant information from each of the fixations they perform, compared to the unsuccessful group. Piras and colleagues [25] suggest that higher levels of cognitive anxiety may increase the number of fixations performed. So the increase in number of fixations performed by the unsuccessful group may be as a result of the increased anxiety as a result of them losing the race, thus their ability to gain relevant information from the environment may be reduced [29, 30].

In terms of percentage viewing time, both groups spent the majority of the race fixating on their boat and the least amount of time fixating on the marks. Most notably, the results revealed that better performances in the simulation were related to gazing more often at the wind indicators. This finding is in line with Araújo and colleagues [7] who concluded that experts were attuned more to the wind indicators compared to intermediate sailors and non-sailors. Interestingly, the unsuccessful group spent significantly more time fixating on the opponent. The difference in time spent fixating on the opponent may be due to the fact that when the opponent was ahead they were the first boat to be affected by any changes in the environmental conditions i.e. a shift in wind angle affected the leading boat first. Thus, the chasing boat can use this information to anticipate the change in angle prior to it affecting them and possibly control their boat better, i.e. be sailing at the correct angle.

The only difference found when comparing the sailing classes was between the percentage viewing times to the OPPONENT location. This may be because the sailors in different classes use visual information gained from their opponents differently. For example the dingy and keelboat sailors spend more time fixating on the opponent compared to the multihull class. The respective absence of differences in performance and visual search variables for the different sailing classes show that all the sailors were performing on the same level during the simulation. Research on expert and near-expert athletes has found that a difference in performance in simulated tasks depends on the expertise level of the athletes and how closely the simulation corresponds to the real-world event [13, 17]. With this in mind the absence of differences may be as a result of the fact that for some of the sailors the task is too removed from what they are used to experiencing in a real-world event. For example keelboat sailors may use more information from the surrounding environment and their own boat compared to a dinghy sailor who might rely more on the actions of other boats for information pick up. The reason for this is that generally dinghy sailors' race with the boats much closer together and the boats are more affected by slight changes in wind strength and direction. The strategies of the sailors from different classes may differ in a real-world setting, which could have affected the results.

To date most research on visual search has used film-based methods [31-33]. Film-based studies are most commonly two dimensional and with reduced image size, which researchers have found affects visual search strategies [17, 18, 34]. This effect may be the reason for the results found. As the distances differ between the computer simulation and a real-world race, the reduced distance from the fixation locations in the computer simulation compared to the real-world makes it substantially easier for the participants to attend to more visual cues using their peripheral vision [17, 35]. Consequently the absence of significant differences for the ranked groups and categorical groups in percentage viewing time in the different fixation locations may be as a result of the sailors being unable to process more information through their peripheral cues.

The computer simulation set out to incorporate the main features of the strategic tasks within sailing and present the event in such a way that no special knowledge is needed for participants to control the sailing equipment [7]. As a result all the sailors could perform the simulation without any training and we are able to compare the results from sailors competing in various classes, specifically dinghies, keelboats and multihulls.

A key element in sport is the athletes' ability to identify when an opponent is going to do something before they do it, i.e. to anticipate their movements before completion [36]. Research has determined that athletes use their visual system to gain information from the movements of the opponents prior to the key action, and that they use this to anticipate the movement [26, 37, 38]. In sailing the athletes use similar visual processes to gain information, however their focus is more on the environmental constrains and different areas of the boat compared to the body parts in other sports such as judo [25], soccer [26] and volleyball [32]. Again due to the nature of the simulation, the results of the study confirm this by suggesting that the sailors highlight the importance of their boat and the wind locations as being important for information pick-up.

As suggested by Cañal-Bruland and colleagues [39], not all visual variables give equally relevant information to the athlete. Thus the results of this research highlight the fixation locations the sailors deem most important. What is interesting to note is although sailors spent minimal time gazing at certain fixation locations (e.g. MARKS), the information gained from them is still necessary in order to navigate the course. The different locations demonstrate distinct differences in sources of information which in turn affect the decisions made on where to position the boat on the course.

Previous research has identified that a simulated event may not always be directly transferrable to a real-world event [38]. However, the nature of this research is the first step in identifying and highlighting the type of information the sailors regard as being important. Now that we know that the critical cues are their own boat and the wind locations we can use this for training, with the aim of teaching novice sailors what to look for in order to be more successful during a race.

3.5 CONCLUSION AND RECOMMENDATIONS

The findings of the study suggest that successful sailors during a simulated event have better visual search strategies compared to unsuccessful sailors and that the dinghy and keelboat classes fixate more often on the opponent compared to the multihull class.

Further research is needed in real-world settings, where the sailors are under normal sailing constraints, to determine if the results are similar. Recent discussion has surrounded the notion that results gained during a simulation are substantially different to those one would find in a real-world event [38]. This is understandable, as the constraints under which the athletes find themselves are different in a laboratory compared to the real-world. However, the benefit of conducting research in a laboratory setting is that the researchers are able to isolate certain characteristics of the individual that they would like to identify and subsequently compare with other athletes [7].

The information gained from the computer simulation in the present study may be used for development purposes. For instance, having novice and intermediate sailors race the simulation while being instructed what to look for and how to use that relevant information to improve sailing performance.

3.6 ACKNOWLEDGEMENTS

This project was completed with the assistance of the Sport Science Department and Centre for Human Performance Sciences at Stellenbosch University (South Africa). The researchers would also like to thank the sailors who volunteered their time to participate in our study.

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CHAPTER 4

ARTICLE 2

Successful National Sailors Exhibit Better Visual Search Strategies during a Radio Controlled Simulated Event

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Abstract

The aim of the present research was to investigate the visual search strategies of South African sailors during a radio controlled stimulated race. Twenty-two sailors completed three radio controlled match races while wearing a mobile eye tracker (ASL Mobile Eye). Races lasted an average of 197.51 (s = 40.05) seconds. Assessed variables included the race performance, the search rate (total fixations, average fixation duration, frequency) and the percentage viewing time. Sailors were grouped according to professional sailing history rank, success rate in the simulation and their respective sailing classes. The results revealed that the top ranking group performed 13.9% fewer fixations per second compared to the bottom ranking group (p = 0.03). In terms of success rate, the successful group exhibited a more efficient visual search strategy consisting of fewer fixations (p = 0.01) of longer duration (p = 0.34). The dinghy class differs between the keelboat class (p = 0.02) and the multihull class in the percentage viewing time to the BOAT HULL location. This suggests that these sailors identified this location as a more valuable source of information.

Keywords: *sailing, visual search, expertise, perceptual skill*

4.1 Introduction

Sailing has recently been gaining more interest from a perceptual-cognitive understanding, specifically the decision-making processes and visual search strategies employed by sailors (Araújo, Davids, & Serpa, 2005; Pluijms, Cañal-Bruland, Hoozemans, & Savelsbergh, 2014; Manzanares, Menayo, Segado, Salmeron, & Cano, 2015). Expert athletes ability to accurately execute the appropriate movement pattern is essential in order achieve their goal, however the contribution of this athletes ability to process the necessary perceptual information is equally as important, as it aids in the movement pattern chosen (Savelsbergh, Williams, van der Kamp, & Ward, 2002). Previous research has found that perceptual-cognitive skills, specifically visual search strategies, might contribute to a successful performance in sport (Ripoll, Kerlirzin, Stein, & Reine, 1995; Williams & Grant, 1999; Mann, Williams, Ward, & Janelle, 2007; Afonso, Garganta, Mcrobert, Williams, & Mesquita, 2012; Pluijms et al., 2014). According to Manzanares et al. (2015) sailing requires a high visual stimulus perception. This is due to sailors having to contend with a number of uncontrollable variables such as the wind, waves and opponents, to make decisions aimed at reaching the finish line ahead of the other boats (Araújo, Davids, Diniz, Rocha, Santos, Dias & Fernandes, 2014). Thus, in order for sailors to be successful they need to be able to extract relevant information from their environment, by which they anticipate events which may occur within an unpredictable environment, adapt to any unforeseen changes and make the most suitable decisions and subsequently improve their performance (Abernethy, Zawi, & Jackson, 2008; Savelsbergh et al., 2002; Williams, Ward, Knowles & Smeeton, 2002).

Previous simulation studies have analysed how sailors control their boats during the pre-start period and what visual information they use to determine the most appropriate place to start on the start line (Araújo et al., 2014). Understandably, experimental tasks should represent the real environment as close as possible (Dicks, Button, & Davids, 2010). However, in some cases this is not possible due to a number of limitations, including the environment to be tested in and the available testing resources. As a result perceptual-cognitive studies in many sports, including sailing, have predominantly been laboratory-based (Araújo et al., 2005; Mulder & Verlinden, 2013; Manzanares et al., 2015). Although a simulation may not directly mimic a real-word event, the sailors are still required to control the angle of their boat and adjustments of sails and interact with the constantly changing task and environment constraints (Pluijms et al., 2014; Araújo, Diniz, Passos, & Davids, 2013). As highlighted by Araújo et al. (2014) these constraints include the wind direction, placement of the marks and movements of the opposition. The radio controlled laser is a one design boat, meaning all the components of the boat are standardised and raced all over the world. As a result, the conditions with which the sailors are required to contend while sailing a radio controlled boat are very similar to those on a big boat, i.e. gaining necessary visual information to determine the best course to sail; identify wind changes and consequently adjust the boat setting for optimal speed and angle and evaluate the relationship between their boat and their opponents (Rocha, Araújo, & Serpa, 1995).

The research to date agrees that expert individuals are more competent and efficient in their ability to select, process and retrieve information to achieve success than near-expert or novices (Sheridan & Reingold, 2014; Savelsbergh et al., 2002; Charness, Reingold, Pomplun & Stampe, 2001). In addition, they are able to achieve this as a result of procedural knowledge from their experience within the sport (Memmert, Simons, & Grimme, 2009; Savelsbergh, Onrust, Rouwenhorst, & van der Kamp, 2006). Some researchers suggest that the greatest difference between an expert and non-expert athlete is the ability to identify key information from specific visual sources within their immediate environment (Savelsbergh et al., 2002; Savelsbergh, van der Kamp, Williams, & Ward, 2005; Savelsbergh, Haans, Kooijman, & van Kampen, 2010). In sailing, experts may be able to identify a wind phase sooner than a non-expert sailor and as a result be able to decide on their next move sooner. This ability for sailors to identify the wind phase is in important factor in determining how they control their boat to best take advantage of the change (Pluijms, Cañal-Bruland, Bergmann Tiest, Mulder, & Savelsbergh, 2015). This links to the perception-action school of thought based on the ideas of Gibson (1979), who suggested that the control an individual has over a movement is based on a “continuous coupling” with respect to the available perceptual information which is constantly evolving (Savelsbergh & van der Kamp, 2000; Savelsbergh et al., 2006; Savelsbergh et al., 2010). Most of the research investigating visual search strategies employed by the different performance levels of the athletes has compared the total number of fixations, the duration of these fixations and the location of fixations, between expert, near-expert and novice athletes. To date research has shown that depending on the task, expert athletes will either perform fewer fixations of longer duration (Mann et al., 2007) or more fixations over less time (Roca, Ford, McRobert, & Williams, 2011) compared to their counterparts.

The present study attempted to investigate the visual search strategies of sailors as they performed a live sailing match race simulation with radio controlled lasers (RCL). This investigation differs from others that have used film, as the environment constantly evolves and, as a result, changes for each sailor.

4.2 Methods

Participants

Participants were recruited via personal involvement, word of mouth, social media and an invitation in an online South African sailing magazine. Twenty two competitive South African sailors (18 males, 4 females), with a mean age of 26 years (s = 9.59), volunteered to take part in the study. The institutional research ethics committee approved the experiment (HS1033/2014). Participants gave written consent prior to participation, and were free to withdraw at any point during the study. All the sailors have on average 15 years (s = 8.54) of professional sailing experience and they sail on average 7 hours (s = 4.17) a week (2 to 16 hours). A sailor (23 years) acted as the “opponent” in the RCL (Figure 4.1) simulation races. The opponent was appropriately matched to the participants in performance standard and years of experience as she adhered to the inclusion criteria. All participants were healthy, had no visual problems and reported no previous racing experience using a RCL.

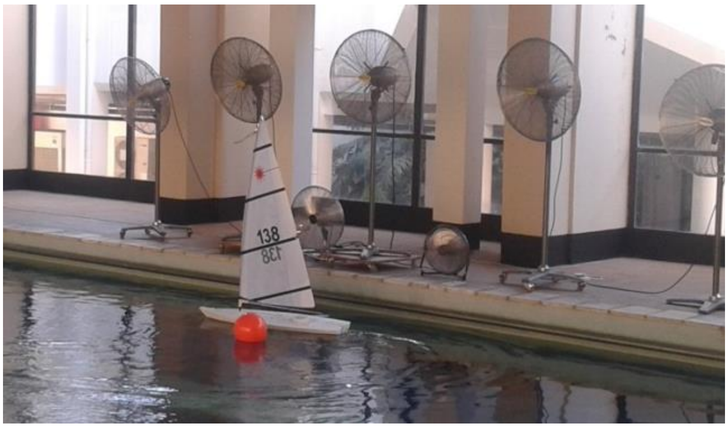

Figure 4.1 Radio Controlled Laser (Picture taken by Claire Walker©).

Apparatus

The ASL Mobile Eye eye tracker (Applied Science Laboratories® (ASL), Bedford, USA) was used in order to determine the visual search variables of the sailors. The Mobile Eye was calibrated to each participant using between seven and nine fixed points at different distances within the environment and participants were unrestricted with their head movements. The ASL Mobile Eye eye tracker has two cameras mounted on a pair of lightweight glasses (Figure 4.2). Before each race, calibration was retained by asking the participants to look at specific points in the environment and confirming that they were correct. The eye tracking data was collected and analysed by high performance specialists (ICC agreement = 0.979). In order to replicate environmental conditions such as the wind, 5 large (70cm diameter) and 2 small (35cm and 52cm diameter respectively) fans were placed at the windward side of the course (see Figure 4.1). Wind speed, generated by the fans measured a maximum of nine knots at the windward mark and four knots at the leeward mark.

Figure 4.2 Sailor wearing ASL Mobile Eye eye tracker (Picture taken by Sarah Arnold©)

Procedure

Participants performed three match races by manipulating a RCL (RCLaser®, RCLaser One-Design) around a predetermined course (Figure 4.3) in the rehabilitation pool (9m x 15m) of the Sport Science Department (Stellenbosch University). Prior to beginning the race, the participants were given five to ten minutes to familiarise themselves with the eye tracker equipment, the controls of the RCL, and the environmental conditions. Participants controlled their RCL with a remote, which allows the participant to manipulate the angle of the boat and the sail settings. Each race began with a 90 second count down prior to the start which was not included in the visual search analysis. After the 90 seconds, the competitors were free to cross the line between the two start marks at the lower end of the pool. Once the line was crossed the participants were required to race up to mark A, down to mark C, up to mark A, down to mark C, back up to mark A and finally down to the finish line (Figure 4.3). The experiment lasted approximately 30 minutes per participant.

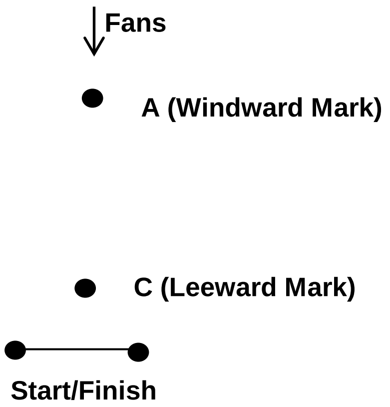

Figure 4.3 A top view of the race course (Start → A → C → A → C → A → Finish)

Point of gaze from the eye tracker was analysed using ASL Results Plus software® (Applied Science Laboratories®, Bedford, USA) and was subject to frame per second analysis. Each trial was tracked from the moment the first boat crossed the start line after a 90 second count down sequence and concluded as the participant crossed the finish line.

Data analysis

Statistical analysis was done using Microsoft Office Excel (Windows® 2010, USA) and XLSTAT® add-in software. Descriptive data was reported as mean ($\bar{x}$), standard deviation (s), percentages (%) and frequency distributions. Data was analysed for normality with a Shapiro-Wilks test. Spearman's Rank correlations (rho) were used to assess the relationship between the sailors' history rank and the visual search variables. A Kruskal-Wallis test was performed on the visual search variables for the whole group. For the analysis of between group data, unpaired t-tests (with pair-wise Fisher LSD correction) were used for parametric data and Mann-Whitney U tests (with pair-wise Bonferroni correction) were used for non-parametric data. An alpha level of ≤ 0.05 was set for all statistical analyses. Cohen's effect sizes (d) were used to establish practical significance and indicate the magnitude of the effect. Effect sizes of <0.15, 0.15-0.40, 0.41-0.75, 0.76-1.10, 1.11-1.45 and >1.45 were considered negligible, small, medium, large, very large, and huge respectively (Thalheimer & Cook, 2002; Cohen, 1992).

In addition, the following variables were used for analysis: race performance i.e. the event duration; while visual search behaviour included search rate (i.e. the fixation location, the total number of fixations, average fixation duration and frequency or fixations/second) and mean percentage viewing time (cumulative amount of time the participant fixated on a fixation location, in %) in each fixation location. After describing the whole groups' race performance and visual search strategies, the participants' data was analysed according to ranking based on professional sailing history rank, the success rate during the simulated events and their preferred sailing class. For the sailing history rank, the participants were ranked by percentiles based on the information they provided in the general information questionnaire, specifically the results they had achieved in national events in the three years prior to the study (January 2012 to January 2015). The sailors were then grouped based on their performances in the races, where successful was defined as having won the race and unsuccessful as having lost the race.

4.3 Results

Of the 72 races sailed, three races were excluded due to too much glare in the video and excessive head movements during data collection, and 22 participants' data was analysed.

Race performance

The whole group of sailors spent on average 197.51 seconds (s = 40.05) completing the course; with the fastest time to complete the race being 145.17 seconds and the longest taking 257.05 seconds. When considering the professional sailing history percentile rank, participants that ranked in the top 50^{th} percentile finished the races in an average of 200.68 seconds (s = 37.97), while the bottom 50^{th} rank finished the races in an average of 194.33 seconds (s = 43.65). The difference in race performance between the groups was not significant (p = 0.69). Finally the sailors were grouped according to their performance on the race. The successful group (n = 22) took an average of 178.31 seconds (s = 43.86) to complete the course, compared to the unsuccessful group (n = 22) who took 218.50 seconds (s = 42.40). The successful group took 20.26% faster in time taken to complete the course compared to the unsuccessful ($p < 0.001$). A Kruskal-Wallis identified no significant differences for main effect in race performance were reported between the three sailing classes i.e. dinghy, keelboat or multihull ($p = 0.48$).

Visual search behaviour

In order to determine visual search behaviours five fixation locations were identified, specifically the BOAT HULL, BOAT SAIL, MARKS, FANS and OPPONENT. The "OTHER" location denotes fixations that were not included in the first five fixation location.

During the RCL match race simulations, all the sailors fixated on average of 328.05 (s = 91.48) times; lasting on average 0.53 seconds (s = 0.12). The results showed an average frequency of 1.65 fixations per second (s = 0.26) for the whole group. The majority of time was spent fixating on the BOAT SAIL (44%) and BOAT HULL (27%) locations, with 12% on OTHER, 8% on OPPONENT and only 4% and 2% of the time was spent fixating the MARKS and FANS, respectively. Further analysis showed significant differences in percentage viewing time between OTHER fixation location and the BOAT HULL, BOAT SAIL and the FANS ($p < 0.01$); as well as between the BOAT HULL location and MARKS, FANS and the OPPONENT ($p < 0.01$). Differences were also found between the BOAT SAIL location and the MARKS, FANS and OPPONENT ($p < 0.001$), in addition to differences between the MARKS and OPPONENT ($p = 0.02$), and FANS and OPPONENT ($p < 0.001$).

Next the sailors were grouped according to their professional sailing history rank (Table 4.1). The only difference for search rate found between the top ranking and bottom ranking groups was for frequency (fixations per second). The top ranking group had 13.9% less fixations per second compared to the bottom ranking group ($p = 0.03$; $d = 1.03$). The total number of fixations were 10.8% ($d = 0.41$) less and the average fixation duration 13.3% ($d = 0.58$) longer in the top ranking group ($p > 0.05$).

Table 4.1 Search rate for professional sailing history rank in RCL simulation (n = 22; $\bar{x} \pm s$ with effect size values (d)).

Variables	Top Ranking	Bottom Ranking	Effect Sizes (d)	Practical Outcome	p-value
Total Number of Fixations					
	310.29 ± 82.93	345.80 ± 100.01	0.41	Medium	0.38
Average Fixation Duration (seconds)					
	0.56 ± 0.15	0.49 ± 0.08	0.58	Medium	0.43
Frequency (fixations/second)					
	1.54 ± 0.26	1.77 ± 0.22**	1.03	Large	0.03

** $p \leq 0.05$

Table 4.2 presents the percentage viewing time in each fixation location between the top and bottom ranked groups. No significant differences were found between the groups in the various fixation locations ($p > 0.05$). However, top ranked sailors fixated 5.92% less on the OTHER ($d = 0.56$) and 7.33% more on the BOAT SAIL ($d = 0.71$) compared to bottom rank group ($p > 0.05$).

Table 4.2 Percentage viewing time for professional sailing history rank in RCL simulation ($n = 22$; $\bar{x} \pm s$ with effect size values (*d*) calculate on absolute differences).

Variables	Top Ranking	Bottom Ranking	Effect Sizes (*d*)	Practical Outcome	p-value
Percentage Viewing Time (%)					
OTHER	8.22 ± 7.49	14.14 ± 13.64	0.56	Medium	0.60
BOAT HULL	28.85 ± 10.37	29.22 ± 8.95	0.04	Negligible	1.00
BOAT SAIL	49.07 ± 10.72	41.74 ± 11.05	0.71	Medium	0.26
MARKS	3.93 ± 1.46	4.21 ± 1.44	0.20	Small	0.66
FANS	1.95 ± 2.40	2.72 ± 2.22	0.35	Small	0.26
OPPONENT	7.97 ± 2.43	7.98 ± 3.13	0.00	Negligible	1.00

Spearman Rank correlations were conducted on the visual search data in order to identify if the ranking of the sailors had any relationship with their search rate and percentage viewing time. No correlations were found between the above mentioned variables ($-0.16 \leq rho \leq 0.31$, $P < 0.05$).

The groups based on the outcome of the RCL simulated races revealed a 20.1% difference between successful ($\bar{x} = 296.89$, $s = 89.35$) and unsuccessful ($\bar{x} = 363.39$, $s = 106.62$) groups in total number of fixations ($p = 0.01$) (see Figure 4.4). Although the successful group performed fewer fixations compared to the unsuccessful group; the frequencies of the groups were identical ($\bar{x} = 1.66$, $s = 0.28$).

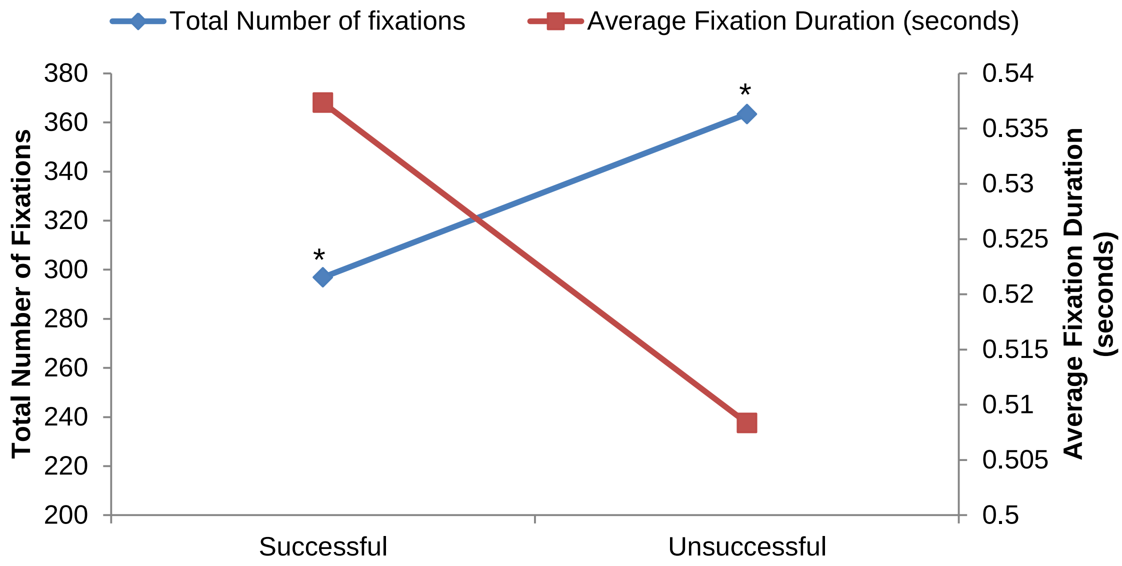

Figure 4.4 Search Rate for Successful and Unsuccessful Groups in RCL Simulation (n = 22) * $p \leq 0.01$

Figure 4.5 presents the percentage viewing time for the successful and unsuccessful groups in the different fixation locations. The results from the OTHER (p = 0.07; *d* = 0.43) and OPPONENT (p = 0.08; *d* = 0.48) locations presented a weak tendency between the two groups; with the successful group fixating less often in both fixation locations. While a medium effect size was noted between the two groups in the BOAT HULL location (p = 0.12; *d* = 0.49). No significant differences were observed for any of the percentage viewing time locations (p > 0.05).

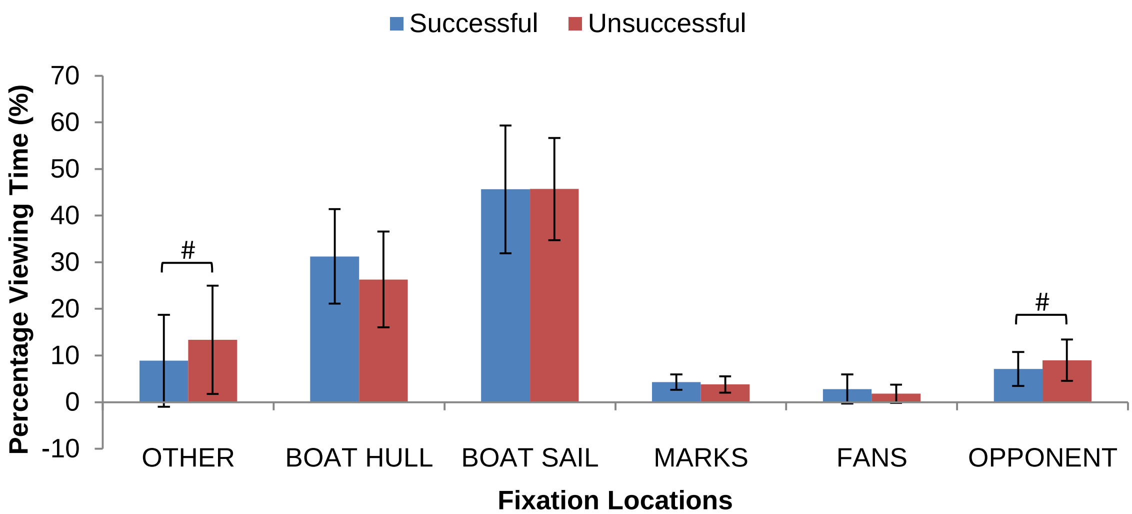

Figure 4.5 Comparison of Percentage Viewing Time in Fixation Locations for the Successful and Unsuccessful Groups

p between 0.07 and 0.08

A Kruskal-Wallis noted a statistical significant difference between the three classes when fixating on the BOAT HULL location (p = 0.02) (Figure 4.6). Further analysis showed that the sailors in the dinghy class differed significantly between the keelboat class (p = 0.02; *d* = 1.94) and the multihull class (p = 0.02; *d* = 1.31); where the dinghy sailors spent 36% of the time in this location, the keelboat sailors 25% and the multihull class 26% of the percentage viewing time. A weak tendency and subsequent large effect size was also observed between the dinghy and keelboat classes when fixating in the BOAT SAIL location (p = 0.09; *d* = 0.76).

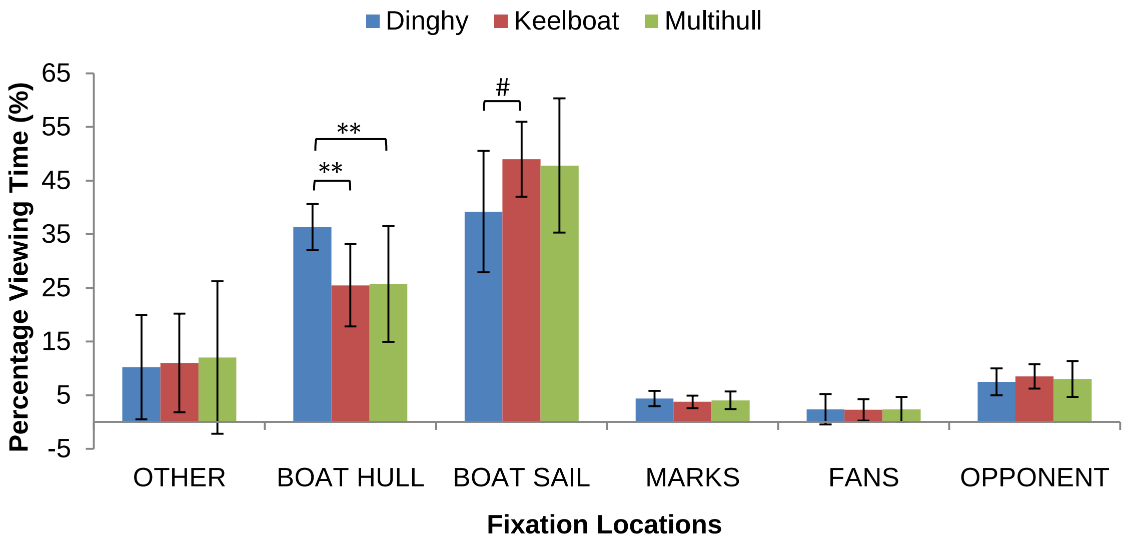

Figure 4.6 Comparison of Percentage Viewing Time in Fixation Locations for the Sailing Classes

** $p \leq 0.05$; # p = 0.09

4.4 Discussion

The main findings of this study were that expert South African sailors predominantly fixate on the boat's sail and hull regardless of their percentile rank and/or success rate. While dinghy sailors fixated more time on the boat's hull compared to keelboat and multihull classes. In addition, top compared to bottom rank, as well as successful compared to unsuccessful sailors performed fewer fixations. Although the study included a simulated and scaled down race, the sailors were still required to react to tactical situations which unfolded as they proceeded around the course. Our findings are in line with a study by Robinski and Stein (2013), who found more experienced pilots were better able to use their peripheral vision in flight and landing procedures.

Expert South African sailors spent the majority of the time (71%) fixating on their boat (hull and sail). This may be due to the fact that the simulation is unfamiliar to the sailors and thus they deemed their boat as the most important location for information pick up in order to achieve the outcome performance goal. This supports the study by Pluijms et al. (2014) who suggest that a faster performance during specific phases of the task was related to a decrease in visual search time spent on fixation locations outside the boat. The group spent an average of 8% of the race looking at the opponent; this is substantially lower compared to the findings of Pluijms et al. (2014). They also only addressed the wind indicators for an average viewing time of 2% during the race. The researchers expected this to be higher, due to the fact that the fans were the only source of environmental change. However, the sailors were also able to use the setting of their sail to determine a change in wind angle; they subsequently spent the majority of the race fixating on the BOAT SAIL location (44%). Thus, they were still able to make decisions based on the changing wind conditions by observing the sail. Sailors control the force of the wind on the sails by adjusting the sails angle with respect to the angle of the wind. The sails propel the boat forward by either having the wind push on the sail from behind, consequently generating force in the same direction of the wind, or by directing the flow in a parallel fashion across the sail, thus allowing the boat to travel in the direction of the wind (based on Newton's Third law). For further understanding see Anderson (2008). Results from the present study suggest differences in search rate between the groups ranked according to professional sailing history. The top ranking group presented a frequency significantly lower compared to that of the bottom ranking group. A lower frequency indicates an athlete's ability to process the information more efficiently, and thus use it more effectively. As a result, an increase in frequency means that it takes more fixations to acquire the same information, thus the athletes decrease their search efficiency (Murray & Janelle, 2003). As seen in the results, the bottom ranking group performed more fixations compared to the top ranking group, and these fixations were of shorter duration. Thus, we can suggest the bottom ranking group employed a less efficient visual search strategy compared to their successful counterparts.

Evidence was also found that the visual search behaviour of the successful group differed significantly from the unsuccessful group. This difference of visual search between the performances of the participants in the simulation was also found in a study by Savelsbergh et al. (2010); where they found differences between high- and low-scoring groups of soccer players. The successful group were able to use the visual information from their boat, the opponent and environment more effectively than the unsuccessful group, which is in accordance with the studies comparing expert and near-expert athletes (Ward & Williams, 2003; Savelsbergh et al., 2010). When comparing the results for the search rate variables, we found that the successful group exhibited a visual strategy involving fewer fixations of longer duration, although the different average fixation durations were not significant. Button et al. (2011) similarly reported longer fixation durations in a simulated event (Button, Dicks, Haines, Barker, & Davids, 2011). Due to the nature of the sport and the fact that the athletes may at some points be overwhelmed with the amount of information available, the differences found between the successful and unsuccessful may be due to their ability to sift through all this information in order to find the relevant cues that will help to improve their performance. The tendency found for percentage viewing time in the OPPONENT location shows that the unsuccessful group spent more time fixating their opponent compared to the successful group. This fixation on the opponent could possibly mean the sailors are attending to a potential anticipatory cue (Afonso et al., 2012). In other words, because the opponent is ahead of them during the race, they are seeing how the conditions affect the boat ahead of them (e.g. change in wind angle) and possibly trying to use this information to best position their boat in order to gain the most from the upcoming change in conditions.

The difference between the sailing classes in percentage viewing time to the BOAT HULL location is interesting in that the dinghy sailors spent the majority of the time in this location. The reason may be that the dinghy class deemed this location most important while navigating the environment. No statistically significant differences were apparent in any other variables. This may be as a result of the fact that the class of boat in which one prefers to race, does not affect the results found in the RCL simulated races.

Simulations allow researchers to assess how sailors explore the task constraints in a more controlled environment. The information obtained allows the researchers to analyse the specific information the sailors are gaining which directs their behaviour. However, we need to consider that the simulation should reproduce the tasks as close to those found in a real-world setting as possible (Ericsson & Ward, 2007). The goals of this simulation are fundamentally the same as those in a real-world race, in that the sailors are still required to manoeuvre their boat as quickly as possible around the course in order to beat the opposition. Consequently one must keep in mind that not every sailor can perform well in this simulation; some sailors were able to understand the controls of the boat very easily while others took a lot longer to get accustomed to the controls of the boat.

One must also acknowledge that the absence of a time constraint may have affected the total number of visual fixations recorded, however not fixation frequency. Due to the fact that the races for the unsuccessful group lasted significantly longer, the sailors invariably made more fixations. However, we need to remember that the aim was to make the simulation as close to real life as possible and that there are no time constraints on sailors to finish a race in a real-setting. The main goal of all sailors is to arrive at the finish line before their opponents. In addition, sport scientists need to consider that the ability to determine where the gaze is at does not necessarily give information on how the sailors are using this visual information. In other words although the sailors may be looking at a certain point they could be storing this information to use later.

4.5 Conclusion

This study highlighted the need for sailors to gain a clearer understanding of the importance of visual skills during a race. During a long race the aim is to limit the sailors' "down time" or time spent concentrating on something other than the race. The results indicate that performance on a simulation is associated with visual search behaviour. By giving sailors cues to look at, the coach or trainer may provide them with specific information regarding the race and their boat sailing performance may improve. Thus, the ability of the sailors to identify critical visual cues is the first step to improving their perceptual skills. Once they have achieved this, they can learn how best to use that information to make the most appropriate decision quicker.

4.6 Acknowledgements

This project was completed with the assistance of the Sport Science Department and Centre for High Performance at Stellenbosch University (South Africa). The researchers would also like to thank the sailors who volunteered their time to participate in our study.

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CHAPTER 5

ARTICLE 3

Executive Functioning Differs Between South African Helm and Crew Sailors

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Abstract

Previous research suggests that competitive athletes have better cognitive functioning skills compared to non-athletes. This study aims to describe the relationship between national-level South African sailors (n = 15) and their executive functions (EF). In addition to assessing global cognition with the Montreal Cognitive Assessment, EF were assessed by administrating a battery of test including the Wisconsin Card Sorting Test, Trail Making Tests A and B, and adapted Stroop task. The results indicate that cognitive flexibility (CF) is an important contributor to success in sailing. Furthermore the EF of the sailors are described according their professional sailing history and then according to the sailor's role on the boat (i.e. crew or helm). The study concludes that top ranked sailors were less distracted compared to bottom ranked sailors and CF differed between helm and crew, with crew demonstrating better CF and inhibitory control. In addition helm had better visuomotor speed and visual scanning. This suggests that CF and inhibitory control (IC), may be important contributing cognitive skills for success in sailing and that scores on EF tests may indicate the role to which a sailor might be best suited for, specifically crew or helm.

Key words: Executive functions, sailing, expertise, sailing role.

5.1 Introduction

A wide range of perceptual-cognitive skills have been investigated in a sporting context (Vestberg et al., 2012). Recently, studies have established a link between physical activity and cognitive functioning (Keating, Castilli, and Ayers, 2013; Jacobson and Matthaeus, 2014). These studies report that once individuals have exercised they tend to score higher on perceptual-cognitive tests, compared to individuals who have done no physical activity (Etnier and Chang, 2009). More specifically, a study done by Vestberg and colleagues (2012) found that elite athletes perform better on tasks assessing executive functioning (EF) skills. This supports the notion that elite-athletes, in a specific sport, have improved cognition within those sport-specific EF skills (Mann et al., 2007; Vestberg et al., 2012).

The term "executive functions" collectively describe cognitive skills such as response inhibition, set-shifting, updating, data processing and problem solving (Diamond, 2006; Chan et al., 2008; Jacobson and Matthaeus, 2014; Dupuy et al., 2015). The current study will refer to three core components of EF namely 1) Inhibitory control (IC), (2) Working memory (WM or updating) and (3) Cognitive flexibility (CF or set-shifting) (for review see Diamond, 2013). Having IC creates the possibility of choice, while WM is used to make sense of what is happening in the immediate environment and possibly relating to what may happen in the future and CF allows switching attention between tasks of varying priorities or take advantage of an opportunity. An individual's WM also allows them to include conceptual knowledge and experiences in order to make a more appropriate decisions or strategies (Diamond, 2013). Miyake and colleagues (2000) suggested that IC, CF and WM contribute differently to the more global executive functions like planning or problem solving.

Decision-making is the "cognitive process of choosing between two or more alternatives" (VandenBos, 2006, p.735). The EF components of decision-making include CF (also referred to as set-shifting) and planning (Chung, Weyandt, and Swentosky, 2014). An example of CF in sailing would be to shift attention from the approaching boat to the wave in front of the boat, to the sail ties; or any unplanned opportunities that may arise in the given moment. Planning on the other hand, is when the athlete is able to decide on a strategy or tactical manoeuver beforehand. For example sailors can look at the course prior to the start of the race and decide that they want to start at the committee boat end of the line, then aim to be the first boat on the right-hand side of the course. A sport such as sailing requires adaptability and quick decision-making in response to external cues from the environment. Thus, sailing is classified as an externally-paced sport. Furthermore, sailing has a huge strategic component as athletes are required to control their own boat, possibly confer with teammates, consider the actions of their opponents and respond to the environmental cues in order to successfully manoeuvre around the course (Araújo et al., 2014). Previous research suggests that athletes who take part in externally-paced activities may have faster and more accurate decision-making processes (Singer et al., 1996; Zoudji et al., 2010). In addition, according to Verburgh and colleagues (2012 and 2014) participation in a tactical sport should lead to better EF.

Given that executive functions have a strong association with decision-making skills (Vestberg et al., 2012; Jacobson & Matthaeus, 2014) the researchers hypothesize that better EF correlates with advance decision-making skills, which may be observed in 1) the sailor's performance and/or 2) the role of each sailor. To date, no studies have investigated the executive functions of sailors. The aim of this descriptive observational study was to identify the EF of South African sailors competing at national level. With the knowledge that decision-making is a crucial component in the success of a sailor, the motivation behind a study similar to this is to determine the cognitive processes of sailors at this level and use this for training. Furthermore, future studies can expand on the information gained in this investigation with the possibility of using the added information for talent identification purposes.

5.2 Methods

Participants

Fifteen South African sailors, of which 87% were male volunteered to participate in this study. Table 5.1 summarises the inclusion and exclusion criteria. Participants were recruited via personal involvement, word of mouth and social media. Participants completed informed consent forms, were told that they could choose to withdraw from the study at any time and that their data would be kept confidential. The Stellenbosch University Research Ethical Committee approved this study (HS1033/2014).

Table 5.1 Inclusion and Exclusion Criteria for All Participants (n = 15)

	Description
Inclusion Criteria	
	– Adults (older than 18 years) – Competed in a national sailing event between January 2012 and January 2015 – Partake in physical activity minimum of three times a week – Prior completion of EF test battery
Exclusion Criteria	
	– Not having sailed within the three months prior to testing – Minimum of 12 years of education – Complaints of memory loss – MoCA score < 17 (moderate to severe cognitive impairment) (Hoops et al., 2009) – Familiarity with the test battery – Colour blindness

Measures

A general information questionnaire (Addendum C) to obtain information regarding participants' demographics (such as age and gender) and their professional sailing history including sailing category and responsibility (role) was administrated. The information provided was used to group the sailors according to their professional sailing history and the role they play on the boat in their preferred sailing class. A cognitive test battery was compiled and included a test for global cognition, i.e. the Montreal Cognitive Assessment (MoCA); and three validated psychological perceptual-cognitive EF tests. These EF tests included the Trail Making Test (TMT; both part A and part B), the Wisconsin Card Sorting Test (WCST), and an adapted version of the standard Stroop task. The specific tests were chosen as they include the cognitive functioning aspects believed to be important and appropriate to sailing.

Montreal Cognitive Assessment (MoCA): The standardised 30-item MoCA for global cognition (maximum 30) was administered in order to screen the participants and ensure that they were not cognitively impaired. A result greater than or equal to 26 is considered normal global cognitive ability (Nasreddine et al., 2005).

Trail Making Test (TMT): The TMT assesses cognitive flexibility (or set-shifting), sequencing and information-processing speed (Sanchez-Cubillo et al., 2009; Lui-Ambrose et al., 2010). Part A specifically assesses visual perception skills such as visual scanning and visuomotor speed and part B focuses on visual spatial skills and CF. Both parts of the TMT include motor speed and agility components (Kortte et al., 2002). Participants performed TMT parts A and B in accordance with the guidelines as presented by Dupuy and colleagues (2015). The two TMT parts are scored separately by total time taken to complete the test (in seconds). To index CF, the score on part A was subtracted from the score achieved in part B (Lui-Ambrose et al., 2010). A higher score indicates a poorer CF ability (Hutchinson et al., 2010; Lui-Ambrose et al., 2010).

Wisconsin Card Sorting Test (WCST): The WCST assess specific components of EF such as CF, which encompasses problem solving, abstract thinking and set-shifting (Heaton et al., 1993). A modest but significant relationship exists between WCST and the decision-making (Brand et al., 2007). During the individually administered test the participant is presented with four stimulus cards (Addendum G), which combine three conditions (colour, form and number). A maximum of 128 cards is presented depending on how many attempts it takes to complete each condition twice. The participant was required to adjust to changing sorting criteria and sort the cards based on a pattern with different parameters (see Buelow et al., 2015). In other words they had to alter their response as the test progressed to achieve a better score.

Adapted Stroop Task: The Stroop task primarily tests inhibitory control (IC), selective attention, and cognitive flexibility (CF) (Lucas et al., 2012). It gives insight into the participants' ability to plan, apply knowledge and make decisions. For this study, a computerized adapted Stroop task consisting of four experimental conditions was used (Figure 5.1); condition 1 and 2 were more simple tasks (naming words and colours), while conditions 3 and 4 were more difficult as they included interference and distraction. The sailors were required to indicate their response by pressing either the left or right arrow keys. See Lucus and colleagues (2012) for a more in-depth description of the adapted Stroop task used. In order to determine a more accurate IC score, the average times to complete condition 1 and 2 were subtracted from condition 3 (IC1). Furthermore, CF was established by subtracting the average times to complete the first two conditions from the time of the fourth condition (CF1). Finally, the average time to complete the first two conditions was subtracted from the average time to complete conditions 3 and 4 (CF2). These additional three conditions of the Stroop task give an indication on the participants' resistance to interference. Interference is when the participant has a prepotent response as a result of a habit and he/she must inhibit the response in favour of another one (Lucas et al., 2012; MacLeod, 1991).

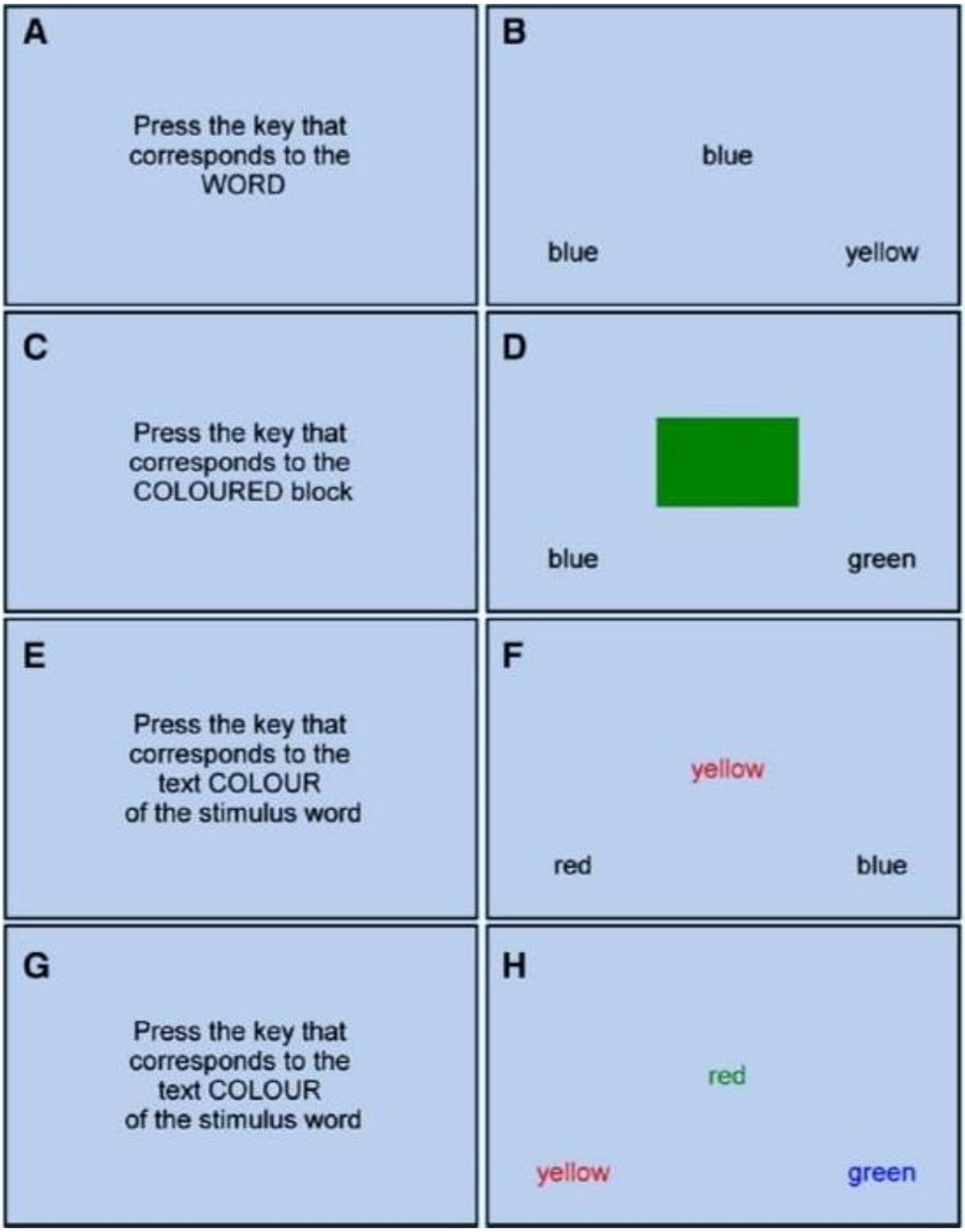

Figure 5.1 Example of trial for each of the four Stroop task conditions, instructions on the left (A, C, E, G) and interactive task on the right with response options at the bottom (B, D, F, H).

Procedures

The participants reported to the Movement Laboratory at the Department of Sport Science, Stellenbosch University. Participants initially filled in the general information questionnaire, followed by completion of the cognitive test battery. The tests were offered in a random order and took approximately 35 minutes to complete.

Statistical Analysis

Statistical calculations were done using Microsoft Office Excel (Windows® 2010) and XLSTAT® add-in function. Descriptive data was reported as mean ($\bar{x}$), standard deviation (SD), percentages (%) and frequency distributions. A Shapiro-Wilks for normality was completed, based on these findings independent *t*-tests (parametric data) and Mann-Whitney tests (non-parametric data) were used to compare the data between the groups. A Spearman rank correlation coefficient was performed to establish if the ranking of the sailors related to their EF scores. Alpha was set at 5%, and tendencies < 0.10. Cohen's effect sizes (*d*) were calculated in order to establish practical significance. Interpretation of Cohen was based on effect sizes of <0.15, 0.15-0.40, 0.41-0.75, 0.76-1.10, 1.11-1.45 and >1.45 were considered negligible, small, medium, large, very large, and huge respectively (Thalheimer and Cook, 2002; Cohen, 1992).

5.3 Results

Participants

The 15 sailors' ages ranged from 19-50 years ($\bar{x}$ = 24 ± 8 years), had an average of 12 ± 4 years of professional sailing history and indicated an average of 7 ± 4 hours spent sailing per week. All of the sailors had more than 12 year's education.

Executive Functioning

As a group the participants scored an average of 27.80 ±1.47 on the MoCA test. Two of the sailors scored 25, which is borderline indicative of mild cognitive impairment. Table 5.2 summarizes the EF data for the whole group.

Table 5.2 Executive Functioning for Whole Group (n = 15).

Variables	$\bar{x}$ ± SD	Range
Global Cognition		
MoCA	27.80 ±1.47	25 – 29
Trail Making Test (TMT) (seconds)		
TMT A	22.29 ± 5.43	16.22 – 35.57
TMT B	54.06 ± 7.32	44.65 – 67.32
TMT B – A	31.77 ± 6.33	22.93 – 47.50
Wisconsin Card Sorting Test (WCST)		
Total correct	69.14 ± 12.37	61 – 101
Total error	13.50 ± 8.84	6 – 36
Perseverative error	6.50 ± 2.31	3 – 13
Perseverative responses	9.71 ± 3.81	3 – 11
Completed categories	5.79 ± 0.80	3 – 6
Failure to maintain set	0.79 ± 1.48	0 – 4
Stroop Task		
Accuracy		
Condition 1	98.33 ± 3.07	91.67 – 100
Condition 2	98.33 ± 2.11	95.83 – 100
Condition 3	97.50 ± 3.45	87.50 – 100
Condition 4	96.39 ± 4.95	87.50 – 100
Automatic Response Time (seconds)		
Condition 1	0.80 ± 0.11	0.64 – 1.06
Condition 2	0.90 ± 0.13	0.68 – 1.12
Condition 3	1.34 ± 0.20	0.88 – 1.75
Condition 4	1.67 ± 0.27	1.24 – 2.26
IC1	0.49 ± 0.16	0.13 – 0.86
CF1	0.82 ± 0.21	0.49 – 1.21
CF2	0.65 ± 0.16	0.31 – 0.92

IC 1 = Condition 3 - ($\bar{x}$ Condition 1 and Condition 2); CF1 = Condition 4 - ($\bar{x}$ Condition 1 and Condition 2); CF2 = $\bar{x}$ Condition 3 and Condition 4 - ($\bar{x}$ Condition 1 and Condition 2)

The results from the sailors respective national regattas were converted into a percentile, and the sailors were ranked accordingly. Sailors were then grouped based on this ranking, eight sailors comprised the top ranking group (TRG; 22.25 ± 2.25 years) and seven the bottom ranking (BRG; 26.29 ± 10.66 years). The relationship was determined between the sailor's professional sailing history rankings and their scores on the EF tests. Only weak correlations were noted (rho ≤ 0.46; p > 0.05).

As shown in Table 5.3, no statistically significant differences were found for any of the EF variables when comparing the TRG and BRG (p > 0.05). However, a medium effect size was presented between the difference in TMT B and A scores (p = 0.31), with the BRG displaying a lower score. In addition, a weak tendency but large practical significance was observed between the two groups for total correct answers on the WCST. A large effect was presented for the total error in the WCST between the ranked groups with the top ranking group making fewer errors ($\bar{x}$ = 9.57 ± 3.21) compared to the bottom ranked group ($\bar{x}$ = 17.43 ± 11.09). The TRG also showed a medium effect size for completing more categories compared to the bottom ranking (p > 0.05). Additionally, medium effect sizes showed practical group differences in accuracy on conditions two and three of the Stroop test (p > 0.05); with the BRG committing fewer errors in both conditions. In terms of reaction time on the Stroop test, although not significant, the top ranking group were faster in all four Stroop conditions (p > 0.05). Consequently, a large effect size was apparent in the first condition; while medium effect sizes between the groups were found in condition three and four (p > 0.05). After further calculations using the results in the four conditions, medium effect sizes were presented for IC as well as CF1 and CF2 (p > 0.05).

Table 5.3 Executive Functioning for Professional Sailing History Rank (n = 15; $\bar{x} \pm$ SD with effect size values (*d*)).

Variables	Top Ranking	Bottom Ranking	Effect Sizes	Outcome	p-value
Global Cognition					
MoCA	27.75 ± 1.39	27.86 ± 1.68	0.08	Negligible	0.71
Trail Making Test (TMT) (seconds)					
TMT A	21.38 ± 4.72	23.32 ± 6.35	0.38	Small	0.39
TMT B	54.70 ± 8.52	53.32 ± 6.25	0.20	Small	0.73
TMT B – A	33.33 ± 7.56	30.00 ± 4.48	0.57	Medium	0.31
Wisconsin Card Sorting Test (WCST)					
Total correct	63.86 ± 4.95#	74.43 ± 15.54#	0.99	Large	0.08
Total error	9.57 ± 3.21	17.43 ± 11.09	1.04	Large	0.22
Perseverative error	6.57 ± 1.27	6.43 ± 3.15	0.06	Negligible	0.43
Perseverative responses	9.71 ± 0.95	9.71 ± 5.53	0.00	Negligible	0.43
Completed categories	6.00 ± 0.00	5.57 ± 1.13	0.58	Medium	0.39
Failure to maintain set	0.29 ± 0.76	1.29 ± 1.89	0.75	Large	0.26
Stroop Task					
Accuracy					
Condition 1	97.92 ± 3.15	98.81 ± 3.15	0.30	Small	0.46
Condition 2	97.92 ± 2.23	98.81 ± 2.03	0.45	Medium	0.45
Condition 3	96.88 ± 4.31	98.21 ± 2.23	0.41	Medium	0.70
Condition 4	95.83 ± 5.46	97.02 ± 4.64	0.25	Small	0.75
Automatic Response Time (seconds)					
Condition 1	0.76 ± 0.07	0.84 ± 0.13	0.88	Large	0.14
Condition 2	0.89 ± 0.12	0.91 ± 0.15	0.15	Small	0.79
Condition 3	1.28 ± 0.19	1.41 ± 0.20	0.72	Medium	0.22
Condition 4	1.60 ± 0.24	1.74 ± 0.30	0.54	Medium	0.35
IC1	0.45 ± 0.14	0.53 ± 0.17	0.54	Medium	0.36
CF1	0.78 ± 0.21	0.86 ± 0.22	0.43	Medium	0.46
CF2	0.61 ± 0.15	0.70 ± 0.17	0.54	Medium	0.35

# p<0.10; MoCA = Montreal Cognitive Assessment; B-A = difference between part A and B; IC 1 = Condition 3 - ($\bar{x}$ Condition 1 and Condition 2); CF1 = Condition 4 - ($\bar{x}$ Condition 1 and Condition 2); CF2 = $\bar{x}$ Condition 3 and Condition 4 - ($\bar{x}$ Condition 1 and Condition 2)

Sailors were next grouped in accordance with the functional role on the boat, i.e. crew or helm. The EF scores of these two groups are depicted in Table 5.4.

The TMT test showed that the helms were able to complete both trails A ($p = 0.03$) and B ($p = 0.31$) in 30% and 7% shorter time compared to the crews. The TMT A group difference was considered a huge practical and statistical significant difference, with the crews taking an average of 25.37 seconds to finish the test compared to the helms' 18.77 seconds. When considering The 8% difference between the groups for TMT B-A was not statistically significant, but of medium practical difference.

When the WCST was examined, no statistical significant differences were noted between the two groups ($p > 0.05$). However, large effect sizes were found in perseverative error and perseverative responses between the crews and helms. In both cases the crews scores were lower compared to their counterparts (29% and 32%, respectively). Additionally, a medium effect size was noted in categories completed between the two groups, with the helms completing all six categories (maximum score) compared to the crews who completed 5.6 categories ($p = 0.39$).

The adapted Stroop task results showed a statistically significant difference between groups in the fourth condition, with the helms making fewer errors compared to the crews. Interestingly, the helms recorded faster times in the second, third and fourth Stroop conditions when compared to the crews (0.85 seconds, 1.27 seconds and 1.63 seconds, respectively). However, the differences in scores were insignificant (d =0.27 – 0.89). After calculating the score for IC 1, a medium effect size was presented between the groups with the helms achieving a score 14% lower than that of the crews.

Table 5.4 Executive Functioning for Role (n = 15; $\bar{x}$ ± SD with effect size values (*d*)).

Variables	Crew	Helm	Effect Sizes	Outcome	p-value
Global Cognition					
MoCA	27.75 ± 1.39	27.86 ± 1.68	0.08	Negligible	0.71
Trail Making Test (TMT) (seconds)					
TMT A	25.37 ± 5.78**	18.77 ± 1.62**	1.62	Huge	0.03
TMT B	55.93 ± 8.41	51.92 ± 5.68	0.59	Medium	0.31
TMT B – A	30.57 ± 6.05	33.15 ± 6.84	0.43	Medium	0.46
Wisconsin Card Sorting Test (WCST)					
Total correct	67.00 ± 11.18	71.29 ± 13.98	0.37	Small	0.32
Total error	13.14 ± 10.64	13.86 ± 7.47	0.08	Negligible	0.70
Perseverative error	5.57 ± 1.51	7.43 ± 2.70	0.92	Large	0.17
Perseverative responses	8.14 ± 2.48	11.29 ± 4.42	0.95	Large	0.15
Completed categories	5.57 ± 1.13	6.00 ± 0.00	0.58	Medium	0.39
Failure to maintain set	0.71 ± 1.50	0.86 ± 1.57	0.10	Negligible	1.00
Stroop Task					
Accuracy					
Condition 1	98.44 ± 3.10	98.21 ± 3.28	0.08	Negligible	0.94
Condition 2	98.44 ± 2.16	98.21 ± 2.23	0.11	Negligible	0.89
Condition 3	97.40 ± 2.16	97.62 ± 4.72	0.07	Negligible	0.40
Condition 4	98.96 ± 1.93**	93.45 ± 5.82**	1.41	Very large	0.05
Automatic Response Time (seconds)					
Condition 1	0.79 ± 0.07	0.80 ± 0.14	0.12	Negligible	0.84
Condition 2	0.95 ± 0.12	0.85 ± 0.12	0.89	Large	0.13
Condition 3	1.39 ± 0.18	1.27 ± 0.20	0.66	Medium	0.26
Condition 4	1.70 ± 0.24	1.63 ± 0.31	0.27	Small	0.64
IC1	0.52 ± 0.15	0.45 ± 0.16	0.50	Medium	0.38
CF1	0.83 ± 0.20	0.80 ± 0.23	0.12	Negligible	0.84
CF2	0.67 ± 0.15	0.63 ± 0.18	0.32	Small	0.58

** p≤0.05; MoCA = Montreal Cognitive Assessment; B-A = difference between part A and B; IC 1 = Condition 3 - ($\bar{x}$ Condition 1 and Condition 2); CF1 = Condition 4 - ($\bar{x}$ Condition 1 and Condition 2); CF2 = $\bar{x}$ Condition 3 and Condition 4 - ($\bar{x}$ Condition 1 and Condition 2)

5.4 Discussion

Of primary interest were the main effects between EF and the professional sailing history ranks, and the role of the sailors. Even though no relationships between professional sailing history ranking and EF measures were found, the study did demonstrate differences in certain EF skills.

The results when grouped according to professional sailing history rank suggests that WM did not differ substantially between the two groups, however the TRG were more successful in inhibiting distractors such as 'failure to maintain set' (FTMS), with some elements of CF being better (Total error on WCST) and scored faster automatic response times (Condition 1) compared to the BRG. The results with regards to the sailors' roles, suggest that the crews have improved CF and IC (WCST) as well as better automatic response time (Condition 1 and 4), while the helms have better visual scanning and visuomotor speed skills (TMT A).

No significant differences were found when comparing the ranked groups on the TMT test. This suggests that information-processing speed is not a requirement in order to be a top ranked sailor. This is in line with Verburgh and colleagues (2014) who similarly found no difference in information-processing speed of highly- and less-skilled soccer players.

Referring to the WCST, both the TRG and the BRG demonstrated a similar number of categories competed, total correct and total error scores to previous reported results of a similar age group in healthy men and women (Al-Ghatani et al., 2011). However, the Perseverative error (PE) and Perseverative responses (PR) were considerably lower in the sailors compared to general healthy populations (Al-Ghatani et al., 2011). In fact the sailors had about 71% and 61% lower PE and PR, respectively than healthy participants of the same age and education reported previously (Al-Ghatani et al., 2011). Perseverative scores are indicators of CF (Kortte et al., 2002, which suggest that expert sailors have better CF than health age-matched peers. Compared to the BRG, the TRG differed most significantly in the WCST-of the EF test battery. Interestingly, the BRG made more correct choices compared to the TRG. However, they also made more errors during the test. Furthermore, when considering the total number of cards each group received (TRG received 73 cards & BRG 92 cards out of a possible 128), the BRG showed a success rate of 81%, compared to the top ranking's 87%. This indicates that even though the BRG had more correct answers, they also had received more cards to be able to finish the set. The fewer cards needed to complete the set, the better the performance on the WCST as seen in the TRG. Thus, the important differences between the two groups are the distinction between the number of errors, and not the number of correct responses. In other words, the TRG presented an error rate of 13% compared to the BRG's 19%. The top ranking group had fewer errors and completed more categories, which confirms the previous statement. Vestberg and colleagues (2012) also reported better EF skills in highly-skilled compared to less-skilled soccer players.

The TRG fundamentally did better in the FTMS variable of WCST compared to the BRG. FTMS is determined by the sum of the number of times an individual fails to sort cards by the specific sorting rule after they have acquired the rule previously (Figueroa and Youmans, 2013). In other words, FTMS is an indication when the sailor changed their sorting strategy incorrectly before they had to. Some researchers state that FTMS assesses distractibility or the inability to maintain attention (Barceló and Knight, 2002), whereas other have said it assesses CF (Zabelina and Robinson, 2010). However, in a comparative study, Figueroa and Youmans (2013) found that FTMS, especially in tasks that require sustained attention, assesses distractibility and not CF. The TRG had a significantly lower score compared to BRG, suggesting that lower ranked sailors were easily distracted and struggled to maintain focus. Figueroa and Youmans (2013) stated that distraction could occur due to various possibilities such as boredom, mind wandering or the inability to maintain task goal. This implies that BRG may not have been able to maintain the task goal and thus lost interest and became distractible or vice versa, while the TRG were able to inhibit distractions and therefore focus better on the task at hand.

Overall the whole group scored predominantly better ‘percentage accuracy’ than previously reported data for Stroop task condition 1 to 3, as well as IC1 (Al-Ghatani et al., 2011), but similar to other studies for the same age group and education levels (Zimmermann et al., 2015). Naming words (condition 1) and naming colours (Condition 2) relates to automatic responses, whereas naming incongruent colour-words conveys information about IC and CF (Zimmermann et al., 2015). Comparable to the group differences in the WCST, the Stroop task showed that the TRG were able to respond faster in all four conditions but with both groups showing similar accuracy scores. The biggest difference between the two groups was found in Condition 1. Even though the TRG was slightly more able to inhibit already planned responses and possibly resolving conflicts better, this was not significantly different between the two groups.

The study results also show that a connection between the role of the sailors and their respective EF skills for certain measures. The differences in EF between crews and helms may be a result of their responsibilities on the boat. Helms had better visual perception skills such as visual scanning and visuomotor speed as shown in TMT A, but only slight differences in visual spatial skills and cognitive flexibility between the two roles according to the TMT B and TMT B-A data. The WCST results indicate that the crews had notably better perseveration skills. In other words, the helms kept on making repetitive responses to a stimulus despite a change in the stimulus which actually required a different response (Tchanturia et al., 2012). The lower PE and PR of the crews suggest that they have better CF and perhaps to some extent IC, as supported by Condition 4 in the adapted Stroop task and to some degree the TMT B-A. This means that the crews could anticipate the next event/action better than the helms, and as a result are able to actively adjust between strategies in ever changing environments (Figueroa and Youmans, 2013).

Interestingly, the results revealed that the crews were sometimes slower when responding to a stimulus in the Stroop task compared to the helms; however they were considerably more accurate during the interference task (Condition 4). This could suggest that the crews may have used a more conservative type of response strategy during the course of the test. Verburgh and colleagues (2014) suggested that highly talented soccer players may have used a similar strategy. In addition no significant differences were noted in processing speed in Condition 1, although a difference was apparent for Condition 2. These two Conditions present information on the automatic responses of the participants, thus we suggest as a result of the difference in Condition 2 that the helms have faster responses.

Furthermore, the outcomes indicate the potential for determining the success of a sailor in a respective role based on EF skills, i.e. if an individual has better CF and IC they are most likely better suited for crew, and if they have better visual scanning skills and visuomotor speed they could be more proficient as a helm. However, more research is needed to confirm these findings. These differences may be because the different roles acquire a different cognitive ability or different demands on the sailors. For example, the main aim of the helm is to maintain the speed and keep the boat driving forward in the existing conditions. As a result they may be focusing on the waves and wind directly in front of the boat, which requires quick reaction time. While the crew has more time to keep their focus outside of the boat, suggesting that their responsibility is to identify the fastest course to take on each leg, look for opportunities and keep track of the boats around them. Better CF in the crew would allow them to anticipation of the next event better.

Previous research has suggested that differences in EF skills are found when comparing athletes from externally-paced and self-paced sports (Jacobson and Matthaeus, 2014). Jacobson and Matthaeus (2014) found that externally-paced athletes outperformed self-paced and non-athletes on problem solving tasks, while self-paced athletes outperformed externally-paced and non-athletes in an inhibition task. Zoudji, Thon and Debû (2010) suggest that athletes competing in externally-paced sports may have faster and more precise decision-making skills. Keeping in mind that sailing is an externally-paced sport, where the environment is constantly changing we would expect sailors to achieve better scores on tests specifically examining problem solving, such as the WCST. The fact that the helms scored better on the inhibition task may suggest that their responsibility requires cognitive processes much like those of self-paced athletes. While the crews are required to solve the problem of understanding and making sense of the environmental conditions, and as such have a more developed ability to make-decisions and recognise patterns. Given the nature of the sport, and the notion that it requires the involvement of multiple cognitive domains, the higher scores in some of the tests are not surprising. The sailors are required to obtain a high level of planning and have to execute specific actions and tactical manoeuvres in order to achieve their goals.

A study on the decision-making skills of sailors has suggested that expert sailors are better able to use the available information when compared to near-expert and novices

(Araújo, Davids and Serpa, 2005). They are able to extract more relevant task information from the environment, resulting in an ability to complete the course ahead of their competitors. This study thus provides a link between the decision-making skills and executive functioning of top ranking and bottom ranking sailors, such that the top ranking sailors showed better scores on the WCST. Indicating better cognitive flexibility, and predominantly the TRG was less distractible as seen in FTMS.

Limitations of this study include the small sample size, which reduces the generalisability of the results. Furthermore, research has suggested that the EF skills of an individual decrease with age (Park et al., 2001). Thus, the wide range in ages of the sailors might have had an influence on the results. In addition, we included the two sailors who scored 25 on the MoCA, this score indicates mild cognitive impairment which may have influenced the results and subsequently biased the group they fell into. Finally, the testing battery in the current study may not be sport-specific enough to determine all the differences in EF in the sailors.

However, despite these limitations the results suggest that cognitive flexibility is an important contributor in order to achieve success in sailing. In order to determine which role an individual may be successful in, the data suggests that specific scores on validated cognitive tests may establish if a sailor is better suited and more likely to achieve success in a crewing or helming role. Thus, the present study may change how future sailors choose their role on the boat and may have a marked impact when putting a team together such in the Volvo Ocean Race or America's Cup. Future studies should aim to conduct research on EF of athletes using the same perceptual-cognitive tests in order to be able to compare the results from different studies and subsequently from different sports. Williams and Ford (2008) suggested that these results will also help us to understand skill transfer across different types of sport.

5.5 Conclusion

The main findings of this study suggest that the TRG of sailors were better able to selectively attend to specific cues and consequently were less distractible compared to the BRG. Furthermore, the crews demonstrated better CF and IC while the helms showed better visual perception skills, specifically visual scanning and visuomotor speed. Predicting talent and subsequent success in sport is very risky, as the performance of an athlete at the present moment is not a definite measure of their performance in the future (Vestberg et al., 2012). The data from this study hints at a possible talent identification process, in that future studies including many more participants can be done in order to determine normative values. Thereafter, an athlete can complete the same test battery and compare their scores to those represented in by the normative values.

5.6 Acknowledgements

We acknowledge the support of the Sport Science Department (Stellenbosch University), and thank the sailors for their participation and contribution to this study.

5.7 References

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CHAPTER 6
GENERAL DISCUSSION AND CONCLUSIONS

6.1 Introduction

In this investigation, the primary aim was to determine the visual search strategies of sailors during simulated races within relation to their decision-making cognitive processes, referred to as executive functions (EF). In summary the study found that the most important areas in a simulated sailing environment for information pick up comprise the boat and wind locations. Furthermore, the top ranked group (TRG) of sailors in the radio controlled laser (RCL) simulation performed fewer fixations per second compared to the bottom ranked group (BRG). The EF tests further demonstrated this as they showed that the TRG were less distractible, with better cognitive flexibility (CF), than the BRG. In addition, the sailors who were successful in the simulations adopted a more efficient visual search strategy consisting of fewer fixations of longer duration. The findings from the EF tests established that differences exist in certain EF skills between the roles of helm and crew on the boat. Specifically; the crews displaying better CF and inhibitory control (IC) while better visuomotor speed and visual scanning were noted for the helms. The main findings in relation to the research question are outlined below.

6.1.1 Participants

All of the sailors who volunteered in this investigation were of a similar skill level, i.e. they had all competed in a South African National event between January 2012 and January 2015. However, the present investigation did find some evidence for differences in this homogenous group of South African sailors.

The sailors in study 1 to 3 indicated that they had on average fourteen, fifteen and twelve years professional sailing experience, respectively and spent on average 6.97 ± 0.42 (between 6.58 to 7.41) hours sailing per week. Previous research on dingy sailors, who prepared for the 2004 Olympic Games, indicated that sailors trained on average 31 to 35 hours per week in preparation for their competitive season (Chamera, 2004). This is far more than what the current study's sailors trained, however the sailors were assessed during their off season. Other research has also reported in a significant reduction in sailing time during the off and pre-seasons for experts (Legg, Mackie, & Slyfield, 1999b). In addition, many sailors in South Africa are fully employed, which when compared to sailors training for the Olympic Games for example allows for substantially less time to train during the week. Consequently, these sailors are limited to only training on the weekends, resulting in fewer hours spent on the water per week. One also assumes that during this off season, sailors have far less competition-related stress. As stated previously stress and anxiety could influence EF as well as decision-making skills (Preston et al., 2007). Therefore the results found in this investigation may differ if the sailors were tested during their competitive sailing season, as well as between sailors in developing and developed countries.

Age has an influence on cognitive skills, i.e. a decline in EF (Apfelbaum, Krendl, and Ambady, 2010). Subsequently, the age range of the participants in study 3 (Chapter 5), between 19 and 50 years, might have had an influence on the results. Specifically, a decrease in working memory (WM) has been reported in older individuals (Hartman, Bolton, and Fehnel, 2001). This suggests that that the EF tests which include CF would not have been severely affected by age, but those testing for WM would be. Furthermore, normative values used when comparing scores on EF tests are generally categorised based on the age of the individuals, making comparisons of the group results sometimes problematical.

6.1.2 Which visual search strategies do sailors employ during simulated races?

In both visual search studies the sailors had a top-down perspective of the course, i.e. they could see the whole course from their position and as a result make decisions in a controlled environment. The fixation locations, search rate and percentage viewing time to each fixation location was analysed to determine the visual search strategies of the sailors.

The percentage viewing time highlights the importance the sailors give to each location and illustrates the participants' visual search pattern. When looking at the visual search strategy of the whole group of sailors (articles 1 and 2), sailors from both the computer and RCL simulations looked most often at their BOAT. This suggests that when navigating a simulated course, the sailors rely most often on the information from their boat in order to achieve the task goal, i.e. navigating the boat around the course and attempting to finish ahead of the opponent. This result was also found by Manzanares et al. (2015).

Interestingly, both Manzanares et al. (2015) and Araújo et al. (2005) emphasised the importance of the wind as a critical cue for successful sailing performance. Subsequently, at first glance, the findings of the current investigation seem to contradict these previous two studies, as the sailors in the RCL simulation spent minimal time looking at the FANS. The notion is that the FANS presumably gave vital information about the wind direction.

However at closer examination, the data shows that the sailors in the RCL fixated mostly (44%) on the boat's sail, and then the boat's hull (22%). Due to the simulated nature of the study, the sail may give the sailors more relevant information about the wind and what actions to execute then the actual fans; whereas the sailors in the computer simulation spent the second longest time, after the BOAT location, fixating on the WIND markers. In a race the sailors are able see and anticipate the pattern of wind as it moves across the water. As a result sailors are able to adjust their sails in advance in order to take full advantage of the change in wind. Once the wind reaches the boat it will either allow the sailors to steer their boat closer to the wind or will force them away from it. The sailors need to make this adjustment in order to maintain optimal boat speed. If however, a sailor is not able to anticipate the wind change they will rely on information from the sail, such as tell tails, regarding a change in wind angle. Therefore both Manzanares et al. (2015) and Araújo et al. (2005) support the findings in the current investigations. Other reasons for the difference between the two studies may be that the RCL task was more difficult, thus the sailors had to look at their boat more often in order to control it, or that the fans were in their peripheral vision thus they did not need to look to that location as often. Furthermore, there were many more wind indictors in the computer simulation and they changed on a more regular basis, thus making it more important for the sailors to keep track of the wind marker changes. The same fixation locations and rating of importance were identified irrespective of separating the groups into top and bottom rank or successful and unsuccessful groups.

Abernethy (1991) suggests that experts are consistently able to make better decisions through the use of visual information and knowledge structures. As a result sailors gain relevant information from the environmental conditions around them, and subsequently make decisions based on this information in conjunction with previous knowledge and experience.

Knowledge can be characterised into a) declarative, which is knowledge about the rules of the sport; b) procedural, which is to know what and how to do a movement relating to a task; and c) strategic, which refers to the concepts and strategies related to the sport that can be applied to various situations (Ste-Marie, 1999, McPherson, 1993). Diamond (2013) suggests that the EF component of WM can be linked to these categories of knowledge, more specifically how the athletes use it when making decisions. Araújo et al.'s (2005) study on decision-making in sailors, suggested that the more successful sailors in an interactive computer simulation were more attuned to sport-specific information. This emphasizes the importance of paying attention to critical cues in the sporting context. Araújo et al. (2005) further suggest that when an individual has the opportunity of actively exploring the environment, even individuals with limited knowledge in the task, can achieve success. However, the difference is apparent in that the experts are more successful when considering the overall task goal in comparison to near-experts and novices. This may be due to a more developed strategic knowledge and that they were able to identify relevant information from a wider context as opposed to the immediate space around them, which consequently allowed them to apply appropriate strategies within the simulation. Saury and Durand (1998) also stress the importance of relevant cues for sailors as well as sailing coaches. The cues serve as signs linking the present situation to past experiences (Saury & Durand, 1998).

Search rate gives an indication of the effectiveness of the strategy the sailors' visual strategy. In terms of search rate, research is divided into two schools of thought, firstly that a better visual strategy involves fewer fixations of longer duration and secondly that the strategy involves more fixations of shorter duration. Although the differences found when comparing search rates of the top and bottom ranked groups in the simulations were not significant, a pattern was found in that both TRG made fewer fixations of longer duration. However, the fixation frequency for the RCL differed significantly, which suggests that the TRG made fewer fixations per second. Therefore, these results can be likened to previous research which found similar results when comparing skill level of athletes in other sport (Afonso et al., 2012; Piras et al., 2010; Dicks et al., 2009; Mann et al., 2007; Huys & Beeks, 2002; Savelsbergh et al., 2002; Rodrigues et al., 2002; Singer et al., 1998; Ripoll et al., 1995; Helsen & Pauwels, 1993). The possible reason the top ranking sailors may have implemented this visual search strategy, is that they are able to identify task relevant cues sooner and thus could spend more time fixating on the location and effectively gain more information. Piras et al. (2014) explained that the few fixations and longer durations is a 'simple heuristic' decision strategy i.e. less (in terms of fewer fixations) can be more (in terms of predictive ability). In other words athletes may use less information or require fewer cognitive steps to achieve the target.

When comparing the success rate in the two sailing simulations, the results showed that during the successful races the sailors also made fewer fixations of longer duration when compared to the unsuccessful races. Therefore, different visual search patterns were used between groups with the successful group implementing a more effective visual search strategy. This notion of more effective visual search strategy was described by Savelsbergh et al. (2002), who suggested that a strategy involving fewer fixations of longer duration is more efficient compared to one comprising shorter fixations. The shorter fixation duration of the unsuccessful sailors may be a result of the anxiety they felt when they were losing the race. Janelle and Hatfield (2008) suggest that as anxiety levels of auto race drivers increased, their visual search becomes more erratic.

On another note, previous research has suggested that the ability to actively search the environment enables improved problem solving skills of athletes (Kirlik, 1998). In this investigation, the unsuccessful sailors had an additional challenge in that they had to work out how they were going to overtake their opponent. As a result the unsuccessful sailors may have deliberately been employing a search rate involving more fixations of shorter duration as they were then able to take note of more cues within the environment in order to attempt to solve the problem and achieve the overall goal.

To refer back to the fixation locations, both the successful and unsuccessful groups spent a greater percentage of their time fixating on their boat and the wind indicators. However, the successful group spent more time fixating on the wind, while the unsuccessful group spent more time fixating on their opponent. In both studies the unsuccessful group looked more in the OTHER location; although in the first study the difference was insignificant while in the second a tendency was observed. One must remember that fixation on the OTHER location is not necessarily a negative thing since the OTHER location includes the areas on the water and surrounding environment. This further suggests that the unsuccessful group spent more time actively searching the environment in order to solve their problem.

The diversity in visual search results for the successful and unsuccessful groups may indicate the successful sailors' skill for transforming the available visual information and employing a strategy allowing them to extract the critical information in order to better control their boats. It may also be that the successful group was better at interpreting the unfamiliar information as a result of their procedural and strategic knowledge. Similar results have been found in a number of flight simulation studies. Specifically the study by Staszewski and Davison (2000), where the researchers found that the more successful pilots in the simulation flights were better able to anticipate the consequences of the current situation and as a result make more appropriate decisions. In this case, the more successful sailors were better able to position their boats on the course, maintain awareness of the situation and adapt to the changing environment. The ability for sailors to adapt and constantly make changes has been highlighted by a number of researchers (Araújo et al., 2005). By grouping the sailors according to the success rate of the simulations, the researchers were able to highlight the differences based on skill in the simulations rather than sailing level.

Finally, the sailors were grouped in accordance to their respective sailing classes in which they compete. No statistical significant differences were found when comparing the search rate of the three classes in either of the studies, suggesting that the three sailing classes have similar visual search strategies, possibly because they include similar tasks. However, in the computer simulation the keelboat and dinghy classes fixated more on the OPPONENT location in comparison to the multihull class. This may be because the different classes of sailors use the information from their opponents differently. For example in a dinghy race, the boats remain relatively close to one another while in a multihull race the boats are usually far away from one another when navigating the course and convene at the marks. Additionally, the dinghy class spent 36% of the time fixating on the BOAT HULL location of the RCL simulation in comparison to the 25% and 26% of the keelboat and multihull classes respectively.

Some researchers in the field of visual search have linked the visual search strategies of athletes with their decision-making skills. For example Helsen and Pauwels (1993) examined the different tactical decisions made by expert and intermediate level adult soccer players. They found that the expert players were quicker when responding and their decisions were more accurate compared to their intermediate counterparts. The researchers also suggested that the expert soccer players employed a more efficient visual search strategy, much like the one used by the successful sailors in this investigation. Another study by Vaeyens, Lenoir, Williams, and Philippaerts (2007) found differences when comparing visual search between successful and unsuccessful soccer players on a film-based test specifically aimed at determining decision-making ability. They grouped the soccer players in accordance with their results on the decision-making test into successful and unsuccessful groups, respectively. The researchers established that the successful group used a more purposeful visual search strategy, involving fewer fixations of longer duration. Thus, making them more proficient at adapting their visual search based on the available information, distractors and choices.

6.1.3 Which executive functions do National South African sailors utilize?

The present investigation established interesting findings on EF in National South African sailors. It was also the first study to investigate the EF of sailors. Previous research has established a link between exercise and cognitive ability (Jacobson & Matthaeus, 2014), while other studies have found that athletes have better EF skills when compared to non-athletes (Jacobson & Matthaeus, 2014; Verburgh, Scherder, van Lange, & Oosterlaan, 2014; Vestberg et al., 2012).

In this investigation, the specific EF in which the researchers were interested included elements of problem solving, WM, CF, IC and decision-making skills. Reason being that these components are suggested to be important in order to achieve success in sailing and decision-making. For example a sailor needs to be able to shift their attention (CF) between different areas, such as their boat, opponents, marks and wind indicators, in order to gain relevant and necessary information to make better decisions and subsequently execute more appropriate responses. Sailors should also be able to change the way they react in certain situations out of habit (IC). Consequently selective attention and superior attentional capacity plays a significant role in sailing performances. Verburgh et al. (2014) reported that excellent attentional focus is needed to gather relevant information from the performance context which may allow sailors to anticipate the behaviours of their opponents and environmental conditions.

When comparing the results from the ranked groups, albeit not statistically significant, the large effect sizes showed that the TRG scored far better on the WCST. Laiacona, Inzaghi, De Tanti, and Capitani (2000) showed how to calculate a global WCST score. Based on this global score calculation the sailors overall scored 24.7, which is equivalent to normative values for age-matched healthy individuals (Laiacona et al., 2000). Whilst the TRG had a 92% better global score compared to the BRG (13.4 vs. 36.2, respectively), which is indicative of better CF and IC. In addition, top ranked sailors (TRG) were able to maintain the set in the WCST better and made fewer errors, compared to the BRG (36.16). This suggests that the TRG were less distracted (Figueroa & Youmans, 2013). The assumption is that the BRG has poorer attentional capacity compared to TRG, and is therefore more distractible. Visual search behaviour data of the current investigation supports the finding that TRG were less distracted, unlike the BRG. In the visual search findings the better sailors had fewer fixations and longer durations suggesting that they were able to selectively attend to and better anticipate the events to follow. A strong relationship has also been found between scores on WCST and decision-making (Brand, Recknor, Grabenhorst, & Bechara, 2007) with CF and planning as the EF components of decision-making (Chung, Weyandt, & Swentosky, 2014). Thus, according to these results top ranking sailors are better able to solve problems and make appropriate decisions (Heaton, Chelune, Talley, Kay, & Curtiss, 1993). As stated earlier, in the visual search findings of this investigation, the fewer fixations found in the more successful and TRG may suggest that these better sailors require fewer cognitive processes to achieve a movement goal (Piras et al., 2014). In other words the improved global WCST score, together with the reduced distractibility relates to the visual search behaviour of better sailors.

When considering the results from the Stroop task, moderate practical differences (p > 0.05) were found between the two groups, with the TRG recording consistently shorter reaction times (RT) compared to the BRG. Possibly also suggesting that the TRG are better able to use their inhibitory responses and working memory which is what Verburgh et al. (2014) found in highly talented soccer players. However more research is needed to confirm this finding. The visual search behaviour and EF findings of this investigation imply that better sailors might have experienced less stress and anxiety, compared to the BRG. This could then also explain the possible differences between TRG and BRG; as stress compromises EF, especially the WM, which then reduces the decision-making skills (Preston et al., 2007). Similar Janelle and Hatfield (2008) (as mentioned in visual search section), found that high anxiety levels resulted in erratic visual search behaviours in race drivers. Nevertheless direct assessment of anxiety and stress was not assessed and future studies should take this into consideration.

Like the first two visual search studies in the investigation, the sailors were grouped according to their professional sailing history rank, however in addition the EF study also compared EF relating to the role of the sailors, i.e. crew or helm. The justification for adding this additional analysis was that a sailor’s functional role possibly influences his or her decisions. To the researchers’ knowledge, this is the first study which has compared the EF skills of athletes based on the specific role they play in a team. Interestingly the helms scored significantly lower times on the TMT A trail when compared to the crews and a medium effect size was noted between the two groups for the TMT B trail and TMT B-A, with the helms once again scoring lower times. This indicates that the helms have better visuomotor speed and visual scanning skills compared to the crews. The results show on the other hand that the crews have better CF and to some extend IC as shown in certain Stroop tasks. Thus the crews can switch their actions in response to specific task demands (Ridgel, Kim, Fickes, Muller, & Alberts, 2011). Externally-paced sport like sailing requires adaptability and constant quick emergent decision-making in response to external cues from the environment (Araújo et al., 2005). This emphasizes the importance of EF, such as CF and IC, which would allow expert sailors to respectively adapt and make the most appropriate decision (Araújo et al., 2014).

The TMT is one of the most sensitive tests for EF, particularly part B and the difference between B-A (Kortte et al., 2002). Nevertheless, in the current investigation only non-significant small to moderate practical differences were observed. One possibility is that WM (a prominent component of TMT), even though essential in sailing, does not differentiate between the two performance levels or sailing roles, as CF and IC do. Araújo et al. (2014) found that junior sailors should not memorize actions or strategies, but rather display emergent decision-making behaviours relating again to CF and IC.

When analysing the results from the WCST, no statistical significant differences were found between the two groups. This is also confirmed by calculating the global score between the two sailing roles, i.e. 24.4 vs 25.2, respectively (Laiacona et al., 2000). However, large effect sizes showed practical significance when considering the scores in perseverative error, perseverative responses and categories completed. In this test the results were reversed, in that the crews performed better in the first two above mentioned categories; while the helms were able to complete all the categories suggesting better performance (Yates et al., 2013). This suggests that the crews are more able to think abstractedly and change their mind in response to a stimulus (CF).

Finally, the scores of the Stroop task reflected that the helms were significantly less accurate compared to the crews; indicating a possible speed-accuracy trade off. At the same time, the helms recorded practically significant faster RT in the second and third conditions, as well as the IC1 score. This is suggestive of the fact that the helms have a faster RT to stimuli and that they are more able to inhibit certain responses when compared to the crews. With reference to the slower times of the crews, the reason being that they chose to respond with a conservative strategy. These EF results can be likened to the responsibilities the sailors have while racing, i.e. the job of the helm is to maintain the boat speed, while the crew has more time to look around and develop a strategic plan based on the environmental conditions. The results from the TMT A and Stroop task supports this, in that the helms are required to respond to immediate changes in the wind and waves surrounding the boat. While the results from the WCST suggest that the crews are better able to use their CF. Thus, the results describe the responsibilities of the two roles one can play on the three sailing categories included in this investigation.

During a real-world event, a sailor will employ more than one EF as the event requires a combination of a large number of processes. Thus, while we can suggest that a more successful helm should score better on the TMT and Stroop tasks and that in order to be a successful crew one must score better results on the WCST; we cannot take into account all the EF that may be used at once. The nature of the simulated tests is to describe these EF components individually, thus enabling us to suggest which ones are more relied upon by the different sailing levels and roles.

6.1.4 Simulations vs real-world

Expertise has been defined as the manifestation of skills and understanding from the accumulation of a large body of knowledge. As a result, in order to understand how an expert performs a certain skill or why they are more capable in a specific activity one needs to understand how the athletes structure, access and use their knowledge prior to and during the skill or activity. The nature of research, specifically in the perceptual skills and abilities found in a sporting context, has relied heavily on laboratory testing and simulations. However, the recent advances in technology are allowing for more real-world research.

The advantage of studying skills in a laboratory setting is that the researchers are able to re-characterise the chellenge the athletes have to deal within their sport. This is done by controlling the conditions of the testing environment and isolating the effects of the independent variables. Thus, any relationships found can be attributed to the differences in the individual athletes. The information researchers may gain from the simulation tells them more about the nature of the expert performance and highlights evidence which may otherwise be inaccessible. During a simulated event of the real-world task, the purpose is not only to measure the athletes' efficiency at completing the event but also to gain information about the knowledge structures of the athletes. Throughout a simulation a high amount of importance must be dedicated to the degree the simulation represents the variables from the real-world environment (Williams & Ward, 2003). Williams et al. (2004) stated that research undertaken in a laboratory aimed at identifying perceptual-cognitive demands of a task; need not place the athletes under perceptual-motor demands. Furthermore, Araújo et al. (2005) suggest that simulations provide the participants with an opportunity to explore the task constraints and look for specific information within an environment similar to one they would find themselves in a real-world setting. For example the RCL used as one of the simulations in this investigation, although the simulation is a scaled down version of an actual race, the sailors are still required to react to live tactical situations taking place in front of them.

This use of simulated training as a method for performance improvements in real-world events has been demonstrated by Gopher, Weil, and Bareket (1994). The researchers trained cadets from the Israeli Air Force flight school on a computer simulated game. During the game the cadets were required to complete similar tasks they would find in a real-world situation such as controlling the aircraft, maintaining contact with base and upholding their attention to the task at hand. The cadets received 10 hours of computer game training and performed significantly better in the following test flights compared to cadets who received no such training (Gopher et al., 1994). This highlights the notion of transfer of skills from simulation to a real-world event and the impact simulation training can have on performance.

Previous research indicates that there are differences when testing athletes in a laboratory setting compared to in-situ. Craig and Watson (2011) explain this by suggesting that during laboratory testing the athletes may alter the type of response, i.e. in a live situation they may have less information and thus choose a different decision. The time the athletes receive the stimulus may also differ in a laboratory setting, as well as the quality of the stimulus (Craig & Watson, 2011). For example if the study had a projected video in front of the athletes, they are only able to start gaining information about the situation once the video starts playing. The video may also not show the whole perspective as the athlete would see in a live situation. They suggest that the difference in the nature of these two types of experimentation is significant, particularly for visual search behaviour and movement behaviour. They concluded that the behaviour and choices athletes make in a laboratory compared to field experiment are markedly different. Thus they suggest that further research should be done in real life situations in order to more successfully translate sport-specific knowledge into practical recommendations.
Even though the researcher understands that laboratory research is necessary as the initial phase of applied research, experimental studies in more realistic settings are needed.

6.2 Study Limitations

This study is limited by the following factors:

- There is always a possibility that the calibration of the eye tracker was inaccurate. However, in addition to an experiences eye tracker specialist collecting the data, every possible step was taken to ensure this did not happen.
- Due to the technology being used and the nature of the sport i.e. glare from the water, there was a potential for unusable data.
- Due to the dynamic nature of sailing and the unpredictability of the environment it was difficult to achieve accurate reproducibility between trials on the RCL simulation.
- The simulations presented in the investigation may have been too unfamiliar for the sailors and thus the results we found may be an adaptation to the task rather than their expertise.
- This investigation did not consider the visual search pattern or fixation sequence of the sailors. Manzanares et al. (2015) suggest that the analysis of visual search is incomplete if one does not identify the fixation sequence.

- The performance of the sailors on the EF test may not be able to predict their performance in a real-world event (Chan et al., 2008).
- The researchers did not control for depression and anxiety in the EF part of the study.
- The sample size used in this investigation does not represent every age or ethnic group.

6.3 Recommendations and future research

Afonso et al. (2012) suggest that different results found between a simulated event and an in-situ event may be a result of the different image size and possible actions the athlete can choose from. In keeping with this we suggest that future research look at how these may affect the results and if it is possible to compare the results of different simulations. Furthermore, future studies should consider experimental and longitudinal studies designs and testing during the competitive sailing season.

Research in the perceptual and cognitive skills of sailors should aim to test the sailors during a real event on the water and compare this with performance on the simulated events. Another possibility may be to include simulation training into an expert or near-expert sailors' training program and determine if the implementation of simulation training improves their real-world performance; or to introduce specific training methods to novices that identify specific skills which may lead to expertise. Finally assessing sailors' EF during their competitive seasons or an actual race may add ecological validity.

Using the simulated methods in a training context may benefit the athlete's race performance, with the nature of the simulation; the sailors are exposed to the patterns of the sport. Thus, this research can be used as a blueprint for training tactical and strategic manoeuvres. The athletes have the chance to see the manoeuvre unfolding in front of them and transfer this to their own racing. Once they understand how the manoeuvre works they may be more willing to try it in their own racing. Thus, the information gained from this study provides the basis for the content one would teach to sailors who want to better understand the sport.

6.4 Conclusion

This investigation described the visual search strategies and executive functions of expert South African sailors. The visual search strategies employed by expert athletes are desirable as they are associated with more consistent and successful performances. As a result, many visual search studies, including the current investigation, have motivated that the information gained from their research can improve the training of the near-expert or novice athletes by enabling them to behave like experts.

This investigation has suggested that there are significant differences in the visual search patterns of sailors who are successful and unsuccessful in a simulated match racing event. The visual search strategy employed by the sailors to the relevant visual stimuli is an indication of information needs. The results in terms of percentage viewing time to the various fixation locations seem to be related to the importance of information pick up. Interestingly the TRGs and successful groups in the simulations both employed similar visual search strategies. This suggests that a link might exist between sailing level and performance on the simulations. As a result the possibility exists to use the simulations as a training tool in order to improve sailing performance.

The ability of sailors to identify critical cues from the environment is the first step towards improving their perceptual skills. Once they are able to identify the critical cues from all the information around them, they can then learn to use these to gain the necessary information to make more appropriate decisions. The purpose is for the athletes to gain a clearer understanding of the importance of their visual awareness during a training session or event and as a result, use this to enhance their performance.

In terms of EF, this investigation provides evidence for the notion that different EF skills are associated with different roles on the boat. Specifically, the crews demonstrated better CF and IC while the helms showed better visual perception skills. Furthermore, the top ranking sailors presented with a heightened ability to selectively attend to certain cues; this suggests that they were less distractible compared to their bottom ranking counterparts. This suggests a possible links with the visual search strategies employed by the top ranking as they performed a more efficient strategy. As a result, the information gained from this investigation hints at a possible means of identifying talent within sailing. These findings confirm that CF and IC are important EF for sailing. Future studies can include developing normative values for the test battery used in this investigation for sailors in different roles and performance levels.

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ADDENDUM A

ETHICAL APPROVAL

UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot • your knowledge partner

Approve with Stipulations Notice

Amendment

20-Nov-2014

Walker, Claire C

Protocol #: HS1033/2014

Title: Visual search strategies and decision making in elite and near-elite sailors.

Dear Ms Claire Walker,

Your **Amendment** received on , was reviewed by Research Ethics Committee: Human Research (Humanities) via Expedited procedures on 20-Nov-2014 and has been **Approved with Stipulations.**

Please note the following information about your approved research proposal:

Proposal Approval Period: **30-Jul-2014 - 29-Jul-2015**

The following stipulations are relevant to the approval of your project and must be adhered to: **The researcher must submit a copy of the amended informed consent form for REC review before final approval for the amendment request can be issued.**

Please provide a letter of response to all the points raised IN ADDITION to HIGHLIGHTING or using the TRACK CHANGES function to indicate ALL the corrections/amendments of ALL DOCUMENTS clearly in order to allow rapid scrutiny and appraisal.

Please take note of the general Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

Please remember to use your **proposal number HS1033/2014** on any documents or correspondence with the REC concerning your research proposal

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Also note that a progress report should be submitted to the Committee before the approval period has expired if a continuation is required. The Committee will then consider the continuation of the project for a further year (if necessary).

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) registration number REC-050411-032.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 218089183

Included Documents:
Request for amendment_Research proposal~

Sincerely

Clarissa Graham

REC Coordinator

Research Ethics Committee: Human Research (Humanities)

ADDENDUM B

INFORMED CONSENT FORM

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STELLENBOSCH UNIVERSITY

CONSENT TO PARTICIPATE IN RESEARCH

"VISUAL SEARCH STRATEGIES AND EXECUTIVE FUNCTIONING IN SOUTH AFRICAN SAILORS"

You are asked to participate in a research study conducted by Claire Walker (BSc (Hons) Sport Science), from the Department of Sport Science at Stellenbosch University. The results of this study will contribute to a research project which comprises a Master's degree in Sport Science.

1. PURPOSE OF THE STUDY

The purpose of the study is to determine the visual search strategies and decision-making ability in experienced sailors during a simulated race. Essentially to identify the key anticipatory cues the sailors are focusing on and how they use the information from these cues to make their decisions. Furthermore, the study aims to determine the executive functioning skills of experienced South African sailors.

2. PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following things:

To complete a general information questionnaire, to identify for example the age of the participants, the number of years sailing, dates of regattas sailed in last three years and subsequent results. The participants will inform the researchers of their medical history through the standardized Par-Q questionnaire. In addition if the participant present with any contra-indications they will be referred to a general physician. If the participant wishes to still continue with the project he or she must have medical clearance from their physician. Visiting their general physician (if they wish to continue) will be at the participants own cost.

You will be required to compete in a simulated sailing event at the Department of Sport Science, Stellenbosch, South Africa between January and March 2015. For the first part of the study you will race three match races on a computer simulation (Tactical Sailing©). You opponent will be of similar racing performance level. When completing the races, you will be required to wear an eye tracker (ASL Mobile Eye); in order to track what you are looking at. For the second part of the study, you will race three match races in the swimming pool, using a Radio Controlled Laser (RCL). The races will be on average 4 minutes long and will consist of a Start-A-C-A-C-A-Finish course. As with the previous simulation, you will be required to wear an eye tracker. For the final part of the study you will be asked to complete a battery of valid EF tests, comprising the Montreal Cognitive Assessment, Wisconsin Card Sorting Test, Trail Making Tests A and B, and an adapted Stroop task. These tests will be done in the Movement Laboratory at the Department of Sport Science.

3. POTENTIAL RISKS AND DISCOMFORTS

Due to the simulated nature of this study, this racing holds no serious risk for you.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

Through this research we may find that the visual search patterns differ during different tactical decision-making scenarios around the race course. Furthermore, we hope to determine the executive functions sailors use and identify if any differences exist when comparing the role of the sailors. This study may also benefit the sailing community and other sporting codes which demand the same or similar decisions to be made, visual search patterns, executive functioning or possible training methods. The only direct benefit you will receive from this study is the information gathered during your races and subsequent executive functioning tests.

5. PAYMENT FOR PARTICIPATION

Unfortunately you will not be paid to participate in this study. It is completely voluntary.

6. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of ensuring that the data are saved on the researchers laptop which is password protected. Any paper work will be locked in a cabinet in the Movement Laboratory, Department of Sport Science (Stellenbosch University). This Laboratory has limited access. The only persons who will have access to the information provided by you will be the researcher and supervisor. If this research is published the identity of the participants will remain undisclosed. The participants' anonymity will be established by coding their names e.g. PARTICIPANT 101. In the event that this research is published, no names will be mentioned and only average data will be reported.

7. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you do not want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact the researcher Claire Walker cell: [redacted] email: [redacted] or her supervisor Dr K Welman tell: [redacted] email: [redacted]

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

The information above was described to __________________________ by CLAIRE WALKER in English and I am in command of this language or it was satisfactorily translated to me. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

I hereby consent voluntarily to participate in this study. I have been given a copy of this form.

____

Name of Participant

____ ____________________

Signature of Participant Date

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to ___________________ [*name of the subject/participant]*. *[H*e/she] was encouraged and given ample time to ask me any questions. This conversation was conducted in English.

____ ____________________

Signature of Investigator Date

ADDENDUM C

GENERAL INFORMATION QUESTIONNAIRE

Name and Surname	
Age	
Gender	
Sailing class	
Helm/Crew	
Height	
Weight	

At what age did you start sailing?

____

How many years have you been sailing competitively?

____

Which National and International regattas have you raced in since January 2012?

And what was your result in these regattas?

____

____

____

____

____

____

____

Do you do any fitness training, I.E. a strength and conditioning program for sailing? Please explain.

____

____

____

If yes, how many hours a week do you train?

____

How many hours a week do you spend on the water?

____

Have you ever done any decision training?

____

Do you think decision training will help improve your sailing and racing?

____

Do you wear glasses or contact lenses when you sail?

____

Are you currently, or have you previously suffered from any injuries?

Please give details:

____

____

____

____

Specific sailing related injuries:

____

____

____

____

Have you ever sailed in a Radio Controlled Regatta?

____

ADDENDUM D

PAR-Q

PAR-Q & YOU

(A questionnaire for People Aged 15-69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with your doctor before you start.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check **YES** or **NO**

YES ☐	NO☐	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
YES ☐	NO☐	**2. Do you feel pain in your chest when you do physical activity?**
YES ☐	NO☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
YES ☐	NO☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
YES ☐	NO☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
YES ☐	NO☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
YES ☐	NO☐	**7. Do you have a diabetes or thyroid condition?**
YES ☐	NO☐	**8. Do you know of any other reason why you should not do physical activity?**

If you answered "Yes":

YES to one or more questions

A medical clearance form is required of all participants who answer 'yes' to any of the eight PAR-Q questions.

Note: Personal training staff reserve the right to require medical clearance from any client they feel may be at risk.

- Discuss with your personal doctor any conditions that may affect your exercise program.
- All precautions must be documented on the medical clearance form by your personal doctor.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active - begin slowly and build up gradually. This is the safest and easiest

DELAY BECOMING MUCH MORE ACTIVE:

- If you are not feeling well because of a temporary illness such a cold or a fever - wait until you feel better; or
- If you are or may be pregnant - talk to your doctor before you start

way to go.
• take part in a fitness appraisal - this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professionals.

Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability to persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

NOTE**:** If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME____

SIGNATURE____

DATE____

SIGNATURE OF PARENT______________________________________

WITNESS____

or GUARDIAN (for participants under the age of majority)

CSEP SCPE

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

Supported by: Health Canada Santé Canada

Physical Activity Readiness Questionnaire – PAR-Q

(revised 2006 by CW)

ADDENDUM E

JOURNAL ACKNOWLEDGEMENT - International Journal of Sport Science and Coaching

From: Simon <simonprjenkins@hotmail.com>
Sent: 20 August 2015 12:04
To: Walker, CN, Me <16062876@sun.ac.za>
Subject: Submission of Paper

Dear Claire,

I hereby acknowledge receipt of your paper, "Visual Search Strategies during a Competition Simulated Event in Sailing".

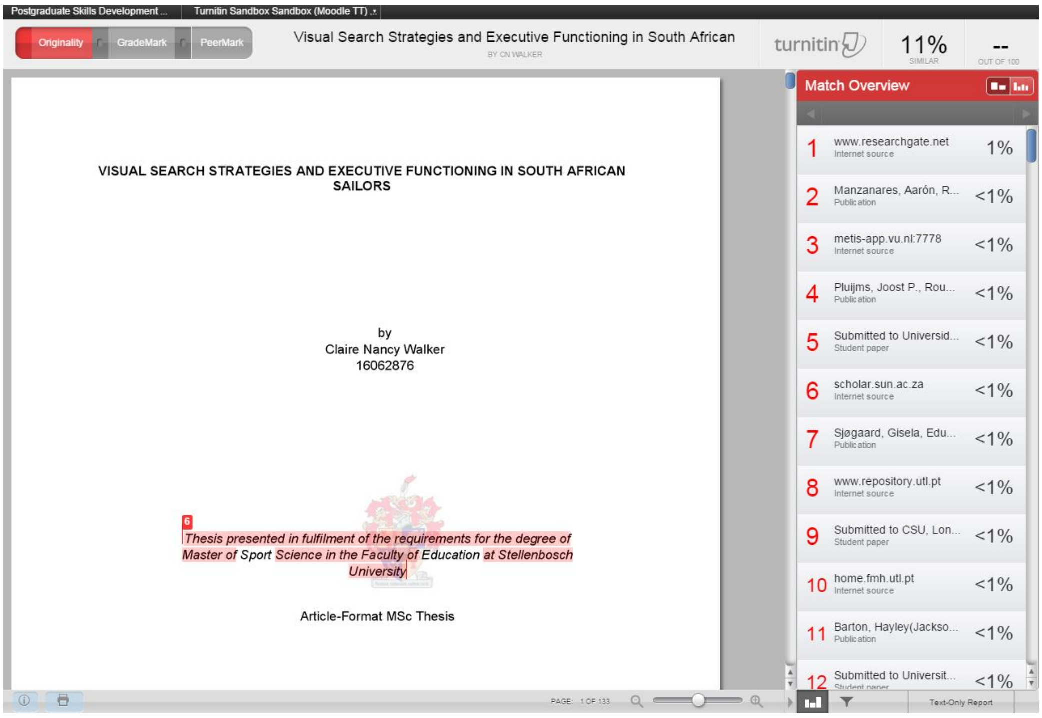
Yours sincerely,

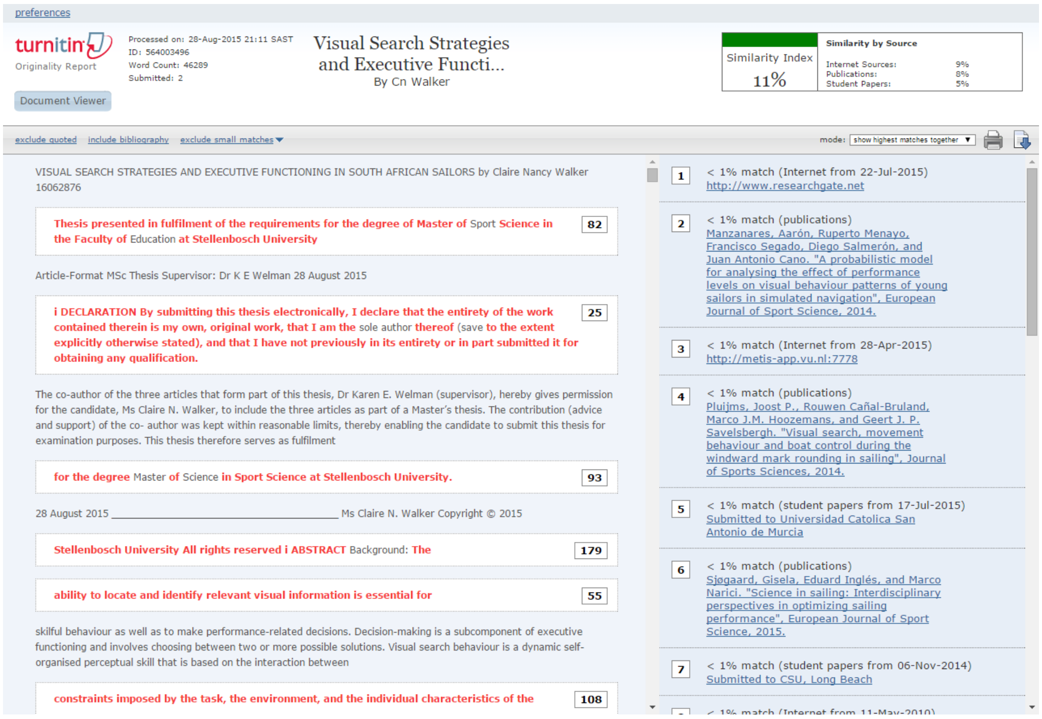
Simon

Dr. Simon Jenkins Editor
International Journal of Sports Science and Coaching
http://www.multi-science.co.uk/sports-science&coaching.htm

ADDENDUM F

TURNITIN REPORT





ADDENDUM G

WCST ILLUSTRATION

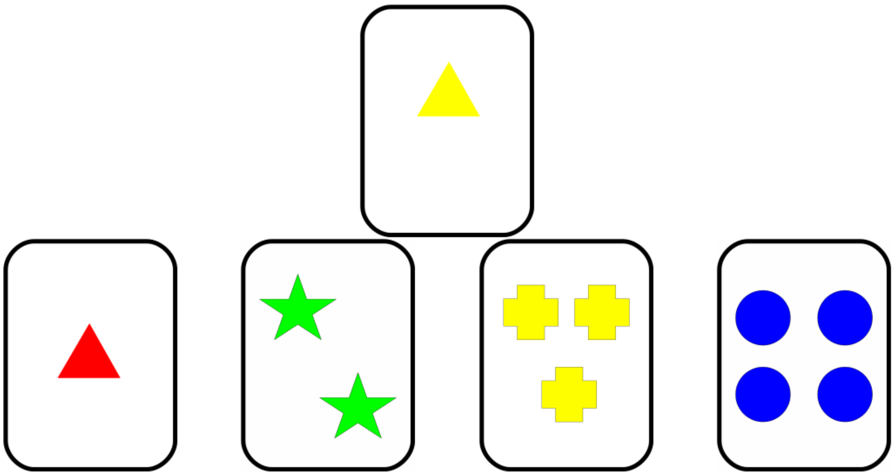


Figure 5.2 (Chapter 5) Illustration of the stimulus cards used in the WCST